FIELD MANAGEMENT IN TEA

TEA RESEARCH ASSOCIATION

TOCKLAI EXPERIMENTAL STATION

Jorhat 785 008, Assam

FIELD MANAGEMENT IN TEA

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FOR TRA MEMBERS ONLY

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TOWARDS INCREASING PRODUCTIVITY IN TEA

J. Chakravartee

In N.E. India yield of tea appears to have reached a maximum plateau around 4000 kg/ha under the best condition of plant and soil. However, the average yield for the region as a whole is less than half this quantity.In order to push the average yield level up, a concerted effort is necessary that involves a systematic approach to identify the crop reducing factors, natural constraints, planning of manpower and financial resources, and at the last but not the least, a comprehensive planning on every aspect of input utilization. The plan should indicate the targetted production in a specific time frame.

I would like to stress that N.E. Indian estates producing far below the potential level are likely to become a liability to the industry and to the nation in the long run. In spite of having scope to produce more with the available agrotechnology, a large number of estates have failed to produce an average yield of even 2500 kg/ha, which is certainly an indication of non-performance. On critical examination of such estates, it was evident that the management of estates were not meeting the requirement of developmental programme like replanting, infilling, shade rehabilitation, soil rehabilitation in an appropriate manner.

Table 1. Yield (KMTH)

Region	1951	1961	1971	1981	1994	1995	1996
Assam	966	1123	1227	1503	1764	1751	1820
West Bengal	982	1043	1176	1365	1589	1593	1621
Total N.E. India	943	1084	1196	1445	1690	1671	1731
Total India	901	1070	1221	1461	1768	1763	1796

[Source : Tea Statistics, Tea Board 1994-95]

However, wide variation in productivity has been observed between and within regions of North East India. On the basis of information generated from 316 TRA member gardens over the period 1990-95, the yield variation in this region is given in the Table 4.

Table 2. Yield (KMTH) variation (1990-95)

Region	No. of T.E. surveyed	Average estate yield	Highest estate yield	Lowest estate yield
Upper Assam	97	2149	2914 *	1206
Mid Assam	56	1573	2498	562
North Bank	58	2087	2609	854
Cachar	20	1359	2104	487
Dooars	53	1889	2569	1116
Darjeeling	23	593	979	198 *
Terai	9	2066	2701	1608
	316	1826	2914	198

Further insight into the scenario reveals glaring variations in productivity even in the best tea growing areas of Assam.

Prolonged research at Tocklai has made it possible to delineate certain areas that required constant attention to increase productivity by 133 per cent during the period from 50's to 90's. Benefits of tea research are availed only by a section of the industry which covers about 75 per cent of tea area and contributes about 85 per cent of N.E. India's production. The difference in productivity between members and non-members of Tea Research Association is estimated to be 56 per cent. With the growth rate achieved in 80's taking the productivity of 1989 as base, it has been estimated that it would be possible to increase productivity @ 100 kg per hectare in Darjeeling and more than 300 kg per hectare in the plains of N.E. India by the end of the century.

To obtain desired productivity, quality and profitability some practices need constant attention.

Factors responsible for low productivity in N.E. India

1. Large area under old tea (45% area are above 40 years age) with high vacancy, poor bush frame and low plant population/ha.

2. Slow rate of replantation (0.52% in Upper Assam and 0.45% in North Bank).

3. Lack of long term policy on the use pattern of planting materials for sustained productivity and quality.

4. High water table problem and lack of suitable outfall for quick disposal of excess water.

5. Soil erosion in hilly area.

6. Lack of proper adoption of agrotechnology.

A serious and systematic planning at all stages is necessary to bring about a breakthrough in productivity.

Young tea

The cost of development has risen day by day due to increase in labour and material cost. The cost of planting, its maintenance and interest burden on it are taken into account for ascertaining pay back period. Increase in the quantum of harvest from young tea plantations would lower the pay back period. The cost requirement for new tea plantation at present is shown below :

Table 3. Cost/ha : New plantation

Item	1st year	2nd year	3rd year	4th year	5th year	Total
Mandays	1303	397	218	184	280	2282
Labour cost (Rs.)	58905	13365	9810	8280	12600	102960
Material cost (Rs.)	84289	16740	14800	14242	14208	144279
Total (Rs.)	143194	30105	24610	22522	26808	247239

NOTE: Labour cost Rs. 45/- per day
1st year cost inclusive of land preparation

Table 4. Yield progression of young tea (above average yield) in different regions (kg/ha)

Year after planting	Region			
	Upper Assam	North Bank	Cachar	Darjeeling
1	504	579	362	43
2	1175	1742	1344	226
3	2248	2209	2050	392
4	2962	2413	2214	523
5	2820	3217	2320	611
6	2979	3330	2499	740
7	3050	3200	2588	805
8	3265	3442	2388	776
9	3105	3791	2252	714
10	3386	4409	2459	707

Seven important field practices adopted for young tea, are of paramount importance to get early return as well as to enjoy a sustainable high yield over a long period. Proper and correct implementation is, therefore, very important. Accordingly these practices are given weightage (expressed in percentage contribution towards potential yield) as given below :

1) Stand density and standard of plants = 20%
2) Pruning skiffing/tipping plucking = 25%
3) Weed control = 10%
4) Balanced manuring = 20%
5) Pest control = 5%
6) Drainage and levelling = 5%
7) Shade = 15%

Some of the weak areas requiring attention have been identified as follows :

1. **Mid and Central Assam (South Bank)** - Shade rehabilitation, infilling, weed control including thatch eradication, adequate treatment against termite damage, faster rate of uprooting and replantation after soil rehabilitation and sub-soiling. Pests build up like *Helopeltis* has been found to be very severe in recent years.

2. **Upper Assam** - Measures to increase productivity of labourers, plucking, replanting with high yielding varieties, drainage and pest control including *Helopeltis* and *termite*.

3. **Cachar** - Infilling, replanting, replacement, control of pests including *termite*, irrigation, erosion control, drainage and bringing up of young tea.

4. **North Bank** - Termite control, irrigation, drainage, shade rehabilitation programme.

5. **Dooars and Terai** - Shade establishment, pruning, pest control including termite, spraying efficiency, infilling, care in bringing up of young tea.

6. **Darjeeling** - Infilling and rejuvenation pruning, erosion control, extension planting, use of improved planting material, bringing up of young tea and bush sanitation measures.

An integrated approach is necessary to improve soil fertility, bush productivity and to break the existing yield barrier. A comprehensive programme of work by each estate is, therefore, of paramount importance. Standards for plant size, soil ferlity, frame architecture, pruning cycle, fertiliser doses have been set and these need to be adopted correctly for the best results.

PLANTING MATERIALS - JUDICIOUS BLEND FOR YIELD AND QUALITY

I.D. Singh and J. Chakravartee

The industry has set a production target of about 1000 million kilograms of made tea by 2000 A.D. This target has to be met through increasing productivity of the existing tea areas as well as through developmental plans of rejuvenation, infilling, replanting and extension plantings. Among the various factors influencing production, soil and plant play major role. Since improvement of soil is a slow process, major increase in productivity could be achieved by use of improved planting materials. Limited yield increase is expected from our existing teas by the use of improved field management practices because of inherently inferior planting materials occupying over 60 per cent of tea areas. Such old teas need to be replaced with proven planting materials suited to different growing conditions of N.E. India.

Genetically improved planting materials differing in yield and quality potential are now available. During the last 44 years 30 TV series clones (Table 1), 134 TRA/Garden series clones (Table 2) and 14 Tocklai biclonal seed stocks (Table 3), besides about 100 industry clones have been released. However, it is essential to adopt a sound policy towards the choice of planting materials in order to meet the ever increasing demand of quality and productivity. Following guidelines may be considered in choosing of planting materials :

1. Clones of diverse genetic origin should be adopted for large scale plantation.

2. Clones with proven yield and quality should be used.

3. Suitability of cultivars for a particular locality could be judged only by growing them on exploratory basis in that locality.

4. Clones may be selected according to their suitability for CTC/orthodox manufacture.

5. A blend of standard, yield and quality cultivars may be in the proportion of 50:30:20 while selecting them for estate planting.

Table 1. Characteristics of TV series clones

Cultivar	Preference for manufacture	
	1st preference	2nd preference
TV1* (AC hybrid)	CTC	Orthodox
TV2* (A)	Orthodox	CTC
TV3* (A)	Orthodox	CTC
TV4* (A)	Orthodox	CTC
TV5* (A)	Orthodox	CTC
TV6* (A)	Orthodox	CTC
TV7* (Ch. hyb)	Orthodox	CTC
TV8* (A)	Suitable for both	

TV9*	(Camb)	CTC	Orthodox
TV10*	(A)	CTC	Orthodox
TV 11*	(A)	Orthodox	CTC
TV12*	(A)	Orthodox	CTC
TV13*	(A)	Orthodox	CTC
TV14*	(Assam hyb)	CTC	Orthodox
TV15*	(A)	Orthodox	CTC
TV16*	(Ass. hyb)	CTC	Orthodox
TV17*	(Ass. hyb)	CTC	Orthodox
TV18***	(Camb)	CTC	Orthodox
TV19***	(Camb)	CTC	Orthodox
TV20*	(Camb)	CTC	Orthodox
TV21**	(A)	Orthodox	CTC
TV22***	(Camb)	CTC	Orthodox
TV23***	(Camb)	CTC	Orthodox
TV24*	(Camb/Spp. hyb)	CTC	Orthodox
TV25***	(Camb)	CTC	Orthodox
TV26***	(Camb)	CTC	Orthodox
TV27*	(Camb)	CTC	Orthodox
TV28*	(Camb)	CTC	Orthodox
TV29***	(Camb, Triploid)	CTC	Orthodox
TV30***	(Camb)	CTC	Orthodox

AC hybrid = Assam X China
A = Assam type
Ass. hyb = Assam hybrid type
Camb = Cambod type
Camb/Spp. hyb = Cambod/species hybrid
Ch. hyb = China hybrid

The clones can be categorised as :

* Standard : Above average yield and quality with yield potential of say 3000-3500 kg MTPH

** Quality : High quality but average yield with yield potential of say 2500-2800 kg MTPH

*** Yield : Average quality but high yield with yield potential of 4000 kg MTPH or above

Table 2. Characteristics of TRA/Garden series clones.

Cultivar		Preference for manufacture	
		1st preference	2nd perference
Assam : South Bank - 49			
Heeleakah	23/4*	Orthodox	CTC
Heeleakah	23/5*	Suitable for both	
Heeleakah	23/9*	Orthodox	CTC
Heeleakah	23/6*	Orthodox	CTC
Heeleakah	22/4*	Orthodox	CTC

Gatoonga	20*	Suitable for both	
Gatoonga	30*	Suitable for both	
Sangsua	6*	Orthodox	CTC
Sangsua	28*	Orthodox	CTC
Sangsua	42*	Orthodox	CTC
Amluckie	84*	Orthodox	CTC
Amluckie	10J*	Orthodox	CTC
Borsillah	3A*	Orthodox	CTC
Borsillah	24*	Orthodox	CTC
Cherideo Purbat	23*	Orthodox	CTC
Dooria	4*	Orthodox	CTC
Dooria	15*	Orthodox	CTC
Gopalkrishna	18*	Orthodox	CTC
Gopalkrishna	31*	Orthodox	CTC
Hulwating	12*	CTC	Orthodox
Hulwating	15*	Suitable for both	
Kaliapani	1*	CTC	Orthodox
Kaliapani	20*	CTC	Orthodox
Kaliapani	25***	CTC	Orthodox
Kaliapani	37*	CTC	Orthodox
Numbernadi	10*	Orthodox	CTC
Numbernadi	42*	Orthodox	CTC
Sangsua	40A**	CTC	Orthodox
Teloijan	22*	Orthodox	CTC
Tingalibam	3/38*	Suitable for both	
Borahi	21*	Orthodox	CTC
Borahi	33**	Orthodox	CTC
Borahi	38*	Orthodox	CTC
Bukhial	21*	Orthodox	CTC
Bukhial	46*	CTC	Orthodox
Dilli	11*	Orthodox	CTC
Dilli	36*	Suitable for both	
Dilli	62*	Suitable for both	
Dilli	72*	Orthodox	CTC
Gabroo Parbat	19*	Orthodox	CTC
Manohari	6/5*	CTC	Orthodox
Manohari	4/16*	CTC	Orthodox
Mokrung	76*	Orthodox	CTC
Thowra	2/11*	Orthodox	CTC
Dahingeapar	24/18*	Orthodox	CTC
Digulturrung	2/14*	Orthodox	CTC
Dinjoye	16*	Orthodox	CTC
Koomsong	23**	Orthodox	CTC
Koomsong	29**	Orthodox	CTC

Assam : North Bank - 27

Choibari	38*	Orthodox	CTC
Choibari	43*	Orthodox	CTC
Choibari	27*	Orthodox	CTC
Bagmari	10*	Orthodox	CTC
Bagmari	20***	Orthodox	CTC

Bagmari	35**	Orthodox	CTC
Dhulapadang	10*	CTC	Orthodox
Dhulapadang	36*	Orthodox	CTC
Gohpur	33**	Orthodox	CTC
Kolony	26*	Orthodox	CTC
Kacharigaon	5*	Orthodox	CTC
Mornai	30*	Orthodox	CTC
Nagrijuli	5/70*	Orthodox	CTC
Nagrijuli	6/24***	Orthodox	CTC
Nagrijuli	7/38*	Orthodox	CTC
Nagrijuli	14/75*	Orthodox	CTC
Tarajulie	34*	Orthodox	CTC
Tarajulie	37*	Orthodox	CTC
Seajuli	16***	Orthodox	CTC
Seajuli	19***	Orthodox	CTC
Seajuli	25*	Orthodox	CTC
Mazbat	107*	Orthodox	CTC
Mazbat	110	Orthodox	CTC
Bormajan	2**	Orthodox	CTC
Bormajan	5*	CTC	Orthodox
Bormajan	9*	Orthodox	CTC
DHUL	41*	Orthodox	CTC

Assam : Cachar - 9

Narsingpore	4*	CTC	Orthodox
Narsingpore	18*	CTC	Orthodox
Narsingpore	22*	CTC	Orthodox
Chandighat	9*	CTC	Orthodox
Longai	17***	CTC	Orthodox
Longai	26*	CTC	Orthodox
Poloi	23*	CTC	Orthodox
Lalamookh	4*	CTC	Orthodox
Lalamookh	7**	Orthodox	CTC

Tripura - 5

Huplongcherra	18***	CTC	Orthodox
Huplongcherra	26***	CTC	Orthodox
Meghlibundh	11*	CTC	Orthodox
Meghilbundh	20*	CTC	Orthodox
Meghilbundh	25*	CTC	Orthodox

West Bengal : Dooars - 5

Hantapara	12*	Suitable for both	
Hantapara	30*	CTC	Orthodox
Huldibri	19***	CTC	Orthodox
Turturi	22*	Suitable for both	
Leesh River	9/34***	CTC	Orthodox

West Bengal : Terai - 10

Mohargung & Gulma	25***	CTC	Orthodox
Sanyasithan	8***	Orthodox	CTC
Sanyasithan	9***	CTC	Orthodox
Sanyasithan	10***	CTC	Orthodox
Sanyasithan	27***	Orthodox	CTC
Sukna	7***	Orthodox	CTC
Sukna	23***	CTC	Orthodox
Sukna	25***	Orthodox	CTC
Kamalpur	6***	CTC	Orthodox
Kamalpur	17***	CTC	Orthodox

West Bengal : Darjeeling - 29

Phoobsering	312*
Bannockburn	157**
Tukdah	145*
AV2	(Balai)*
Tukdah	253***
Tukdah	246*
Bannockburn	777**
Rungli Rungliot	4/5***
Bunnockburn	688**
TV	14*
Tukdah	78*
Tukdah	135*
Tukdah	383*
Rungli Rungliot	17/144*
CP	1***
Phoobsering	1404*
Kopati	1/1**
Happy Valley	39***
Sundaram	(B/5/63)***
Phoobsering	1258*
Teesta Valley	1*
Sikkim	1*
Badamtam	15/263*
TV	19***
Balasun	7/1A/76*
Balasun	9/3/76*
Thurbo	3*
Thurbo	9*
Lingia	12*

* Standard clone : Above average yield and quality

** Quality clone : Clone with very high quality (flavour) and average yield

*** Yield clone : Clone with very high yield but average quality

Table 3. Characteristics of tocklai seed stocks

Cultivar	Preference for manufacture	
	1st preference	2nd preference
TS 378* (14.5.35 x 14.6.28)	Orthodox	
TS 379* (14.5.35 x 14.12.16)	Orthodox	
TS 397 (19.29.13 x 19.35.2)	CTC	Orthodox
TS 449 (19.29.13 x 19.31.14)	CTC	Orthodox
TS 450 (20.23.1 x 270.2.13)	CTC	Orthodox
TS 462 (19.29.13 x 124.48.8)	CTC	Orthodox
TS 463 (19.29.13 x 107.14)	CTC	Orthodox
TS 464 (19.29.13 x 19.29.2)	CTC	Orthodox
TS 491 (19.29.13 x S3A1)	CTC	Orthodox
TS 520 (107.14 x 468.3.13)	CTC	Orthodox
TS 506 (19.29.13 x 19.22.4)	CTC	Orthodox
TS 557 (TRA/AV2 x TA.17.1.54)	Orthodox	CTC
TS 569 (TRA/AV2 x TRA/T-78)	Orthodox	CTC
TS 589 TV20(468/3/13) x TRA/HIK 22/14	CTC	Orthodox

* Stocks suitable for Darjeeling and other hilly areas only.

PLANTING MATERIALS (SHORTLISTED) FOR LARGE SCALE ADOPTION BY TEA INDUSTRY IN N.E. INDIA

Tocklai has so far released 30 TV series clones, 135 TRA/Garden series clones and 14 biclonal seed stocks for the use of tea industry. These materials were categorised based on yield and quality as *standard, yield and quality*.

1) Since clones are different and are not expected to behave uniformly in all soil and agroclimatic zones, for large scale adoption of a particular clone(s), exploratory planting should be done first to know their performance.

2) Secondly, their adaptability to various stress and/or susceptibility to pest and diseases along with inherent quality of the end product become deciding factors for large scale adoption.

3) Long term agricultural trials and data from commercial tea plantations provide clues to such requirements and help the industry to adopt the right material.

4) Genetic base and long term performance in respect of productivity and quality are to be considered for short listing the material from time to time.

5) Short listing of TV series clones and biclonal seed stocks based on above considerations has been made.

6) Some standard TV series clones and seed stocks have by and large proved superior in respect of yield and quality over a long period of time. Hence estates that have already planted sizable area under different clones and yields are much above the district average level, should now concentrate on standard TV series clones and seed stocks alongwith prominent garden series clones.

7) Amongst the TRA garden series clones, short listed ones have proved their above average yield, quality and performance in the nursery.

8) The other garden series clones are to be planted on exploratory basis (small scale) at present to know their growth and yield perfomance so that decision for large scale adoption can be taken later.

9) For Darjeeling, 24 planting materials have been shortlisted for large scale adoption by the industry. Based on available information and keeping in view the need for Darjeeling, it is recommended that the use pattern of planting materials on percentage basis should be as follows :

	Standard	Quality	Yield
Low elevation	30	40	30
Mid elevation	40	60	
High elevation	40	60	

For infilling in low elevation only yield cultivars should be used and for mid/high elevation, standard clones should be used because of their vigour and above average yield and quality.

SUGGESTED PLANTING MATERIALS FOR N.E. INDIA

Regions	Suitable planting materials (clone) TV series clones: Yield	TV series clones: Standard/ quality	TRA garden series clones (Standard) (needs performance planting in the estates)	Suitable seed stocks (Tocklai released) (Standard)	Total number of clones and seed stocks
Assam	TV-22, 23, 25, 26, 29, 30	TV-1,17, 20,24, 27,28 S_3A_3*	Dhulapadang-36, Kolony-26, Barmajan-2, Heeleakah-22/14	TS-491, 462, 589, 520, 463	22
Dooars and Terai	TV-22, 23, 25, 26 29, 30	TV-1,17, 20,24, 27,28	Huldibari-19, Mohorgong/Gulma-25, Barmajan-2,5 Heeleakah-22/14	TS-462, 464, 506, 589, 520	22
Cachar and Tripura	TV-22, 23, 25, 26, 29, 30	TV-1,17, 20,24, 27,28	Narsingpur-4,18, Longai - 17,26 Heeleakah-22/14	TS-462, 464, 506, 520, 589	22
Darjeeling	-	TV - 14.	AV-2, Tukdah-78, 235, 145, Phoobsering-312, 1404, 1258, Lingia 12, RR 4/5[1] Teesta Valley-1* Runglee Rungliot-17/144, Balasun , 7/1A/76,Badamtam-15/263,Kopati-1/1*, Tukdah 253[1], Thurboo-3,9, Happy Valley - 39[1] Bannockburn-157*	TS-379 557 567 378(Nanda Devi)	24

P.S. 1. * S_3A_3 released by Jorehaut Tea Company
2. * quality clones, 1 = yield clones

PHYSIOLOGICAL PROCESSES INFLUENCING GROWTH AND PRODUCTIVITY OF TEA

T.S. Barman and M. P. Sinha

Tea of commerce is produced from young shoots of *Camellia sinensis*. The plant grows into a small tree in nature. But in commercial conditions it is kept in the form of a bush with flat surface for ease in pluckability and to stimulate development of more new shoots. Some of the field practices like pruning, tipping and plucking, shade management, etc. are unique to tea and not found in other crops. All these practices have physiological and biochemical significance in growth of the tea plant. It is important, therefore, to have some understanding of these processes, and then make use of the knowledge for maximum gains.

CROP DISTRIBUTION

Tea is grown in more than 45 countries, ranging from 42° North latitude in Georgia to 38° South latitude in Brazil. Environmental conditions vary in these areas and accordingly there are changes in the physiological behaviour of tea plant. As a result, there is also a change in crop distribution pattern which evidently calls for adjustments in field management practices. In North East India, for example, the crop peak is reached sometimes during June-August (Fig. 1). But in Kericho (Kenya) being on the equator, crop distribution is nearly uniform almost throughout the year where two per cent is harvested every week. In countries like Malawi and Argentina, located in the south of equator, the crop peak is reached during November-January. Likewise different pruning operations also change the crop distribution; unpruned teas giving more early crop than pruned teas.

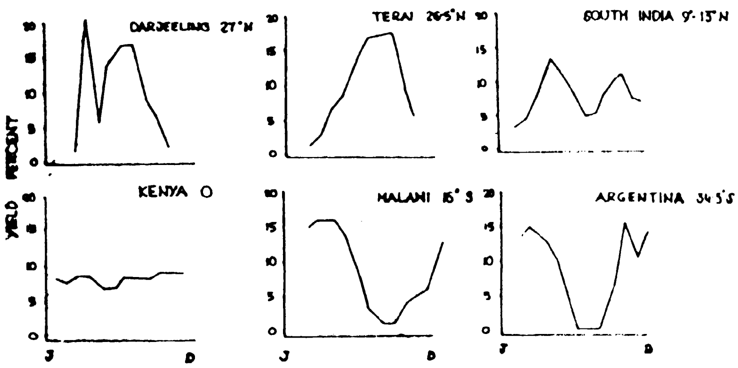


Fig. 1. Effect of latitude on crop distribution

SEED STORAGE

In most crops the seeds are generally well dried before storage. But tea seeds are unusual in the sense that they lose their viability if their moisture content falls below 38-40 per cent. However, if tea seeds are surface sterilized with any suitable fungicide, put in sealed polythene bags and then stored in a household refrigerator at around 5°C, about 60-70 per cent of them remain viable for a period of 10 months. Alternatively the seeds may be treated with 0.5 per cent Jalshakti (a starch polymer), packed in polythenne-lined hesian bag and stored at room temperature. These findings are considered to be of great commercial importance to help transportation of seeds and to defer planting time from droughty spells to favourable periods.

SEED GERMINATION

All tea seeds do not germinate at the same time. This results in uneven growth and creates problems at the time of transplanting. To hasten germination and induce uniform growth of seedlings, treatment with Ethrel at 10-100 ppm was found quite effective (Table 1). Above 100 ppm the effect was supraoptimal and inhibitory. Some other growth regulators were also tried but they were not found so promising.

Table 1. Effect of Ethrel (40% a.i.) on seed germination and its growth 18 days after sowing.

Concentration (ppm)	Seed germination as % taking 100 at 0 ppm	Mean growth of radicle (mm)	Mean growth of plumule (mm)
0	100	22.22	6.67
10	161	34.44	9.67
50	151	31.22	8.44
100	161	29.89	7.33
250	150	29.44	6.00
500	140	28.44	5.00
1000	131	14.79	4.55
CD at 5%	6.26	0.43	0.35

ROOT GROWTH

In both clonal and seedling plants, the feeder roots are the most important for the absorption of water and dissolved nutrients. Therefore, it will be very important to create conditions which favour the development of healthy feeder roots so that the fertilizers applied to the soil are properly absorbed and utilized. Feeder roots are mostly confined to top 30 cm of the soil. The absorbing capacity diminishes gradually as the root ages and the colour changes from white through cream to red. With this change in colour they cease to grow and start rotting. These are then taken up by the new feeder roots and the process of this dynamic equilibrium continues.

In order to have a good root system in tea, it is necessary to have a well aerated, moist and fertile sandy loam soil having pH preferably between 4.5 to 5.5. Rehabilitation improves the structure and porosity of the soil. Proper drainage helps in getting rid of excessive soil moisture and prevents chances of waterlogging. In places with high water table the root system is shallow and generally less efficient. Mulching the ground will cushion the soil against compaction and prevent washing down of finer fraction of top soil. This also reduces the necessity of cheeling (for controlling weeds) and deep forking which no doubt damage the feeder roots considerably. Mulching helps in increasing the soil temperature and microbial activity. All this results in better availability of nutrients and plant growth.

MAINTENANCE FOLIAGE

Permanent leaves retained on the bush, below the plucking table, constitute the maintenance foliage. These manufacture the food and are necessary for the survival and growth of the bush and production of new shoots. This is irrespective of the position of the maintenance leaves, whether on the bush frame or on the primaries. Table 2 shows the effect of defoliation on yield and per cent increase of stem diameter.

Table 2. Number of leaves defoliated, yield per bush and per cent increase of stem diameter.

Treatment	No. of leaves defoliated per bush	Yield per bush (kg)	Increase of stem diameter (%)
Control	0	1.34±0.11	4.74
Defoliation of frame	1175±69	1.10±0.08	3.96
Defoliation of primaries	1452±30	1.10±0.08	3.23
Complete defoliation	2399±111	0.60±0.07	1.69

A leaf does not attain full photosynthetic efficiency until it expands to more than half its maximum size. Even the third leaf in a growing shoot is photosynthetically less efficient than a mature leaf of equal size. In other words the young shoots grow at the expense of the food manufactured by the maintenance foliage, and they are removed through plucking before they start contributing any excess food to the plant. This underscores the importance of having enough healthy maintenance foliage on the bush.

Maximum life span of a tea leaf on a tipped primary is about 18 months. The leaves remain at the peak of their photosynthetic efficiency upto six months after full expansion, beyond which the ageing process starts and their efficiency declines gradually. Hence in perennial plucking there is always a need of adding a layer of new foliage at regular intervals.

[redacted]

Table 4. Relative mean yields of 12 jats of tea.

Particulars	Without nitrogen	With nitrogen	Increase due to nitrogen (%)*
Shade trees absent	100	178	78
Shade trees present	198	236	19
Increase due to shade(%)	98	32	

MOVEMENT OF PHOTOSYNTHATES

Direction of movement of photosynthates from the maintenance foliage is decided by the growing stage of the shoot. When the shoots are growing, the photosynthates move basically in the upward direction to the growing shoots. But when the buds go dormant and there are no growing shoots, the direction of movement of photosynthates is reversed in favour of the roots. Another important point worth noting is that photosynthates never move from one mature leaf to another leaf.

As already explained, in a tea bush under plucking, the growing shoots and the roots are the strong sinks (users of photosynthates) and the maintenance leaves are the source (producers). Flowers and developing fruits also compete for the food produced, but not to that extent as the growing shoots. If flowers and developing fruits are removed, photosynthates going to these organs are diverted for the development of shoots and roots and the productivity is increased. This also explains why hand removal of flower buds in young tea plants increases the root starch reserve and thereby improves the chances of recovery following decentering.

After plucking of the shoot (i.e. removal of the sink) the photosynthetic efficiency of the mother leaf drops to about 65 per cent of what it was prior to plucking. Moreover, the sink capacity of the growing bud diminishes gradually as the leaves unfold. With every unfolding leaf there is a loss of about 30 per cent pulling force on the metabolites from the mother leaf. Thus the relative sink capacities of the growing bud, 1+bud, 2+bud and 3+bud shoots are 100, 70, 40, and 30 per cent, respectively. Likewise the sink capacity of the dormant shoot is reduced to about 50 per cent to that of a growing shoot.

Considering all these facts, 2+bud and 3+bud are the ideal stages for plucking as the loss of sink capacity is minimum at these stages. Growing bud and small 1+bud should never be plucked. Hard banjhis growing above the table should be invariably removed to encourage development of new shoots. Thus in order to maintain the sink capacity, tipping and plucking should be so managed that there is always a large number of growing shoots and the tea bush does not become sink limited.

STARCH RESERVE AND PRUNING TIME

Figure 2 represents the starch reserve in the roots as related to banjhiness. It decides the pruning time for the young and mature tea. Considering the bi-directional flow commencing from October, this may be the earliest time for resting the bushes prior to pruning. Another bi-directional movement occurs in May which may be utilized for centering in young tea if not already done in January/February. It may be noted, however, that presence of good starch reserve in the roots is an important factor to reduce die-back and to have quicker and better recovery of bushes following pruning, but it is not the only factor.

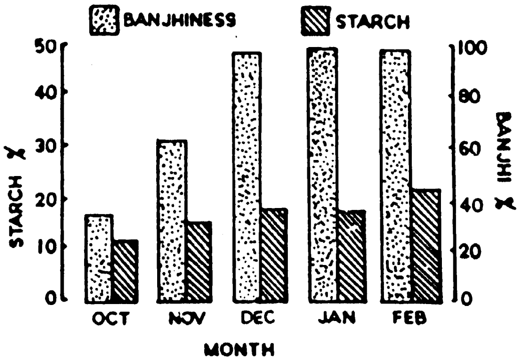


Fig. 2. Starch level in roots and banjhiness of shoots as influenced by season.

BUD DORMANCY

In tea, the growth produced by the terminal bud of a shoot between two successive states of dormancy is called a "flush". "Flush period" refers to the interval of visible growth of the shoot. The rest period between two successive flushes is known as the dormant or "banjhi period". The time required to complete one flush period and one banjhi period is together called "growth cycle". The flushing period of clones varies from 22.6-36.8 days (mean 30.74 days) and banjhi period varies from 19.5-40.4 days (mean 26.37 days). Therefore, to complete one growth cycle (flushing+banjhi period) about 57 days are required. Thus in a year tea plants can complete four flushes only.

Interflush dormancy is perhaps caused by the slow rate of maturation and development of the tissues in the growing shoot that is not able to keep pace with the fast growth, and therefore the shoots go dormant. Shoots may also go dormant because of low availability of moisture from the soil and various other factors.

Winter dormancy, on the other hand, is caused by the interaction of some environmental factors like short day length and low temperature. However, by raising the temperature and/or providing continuous illumination we have not been successful so far in preventing the onset of winter dormancy, but the length of dormant period can be reduced to some extent by these treatments. We lack information on the value of critical temperature and day length below which each acts as a limiting factor. Experimentally it has been proved that maintenance leaves carry out photosynthesis throughout the year. Therefore, it is not the stoppage of photosynthesis which makes the bushes go dormant.

Both in winter and interflush dormancy it has been seen that with the change in the growing pattern of the shoot, there is also a change in the endogenous growth promoters/inhibitors ratio. A high ratio makes the shoots grow, and a low ratio makes the shoots go dormant. Accordingly, the direction of movement of photosynthates from the maintenance leaves is also decided.

Therefore, the object of plucking is to produce maximum number of growing shoots, and to remove these fast before they go dormant and there is any change in the direction of movement of photosynthates. Auxins, cytokinins and gibberellins are the growth promoters and abscisic acid and ethylene are the growth inhibitors. Their balance is determined by the environmental and genetic factors.

Spraying with growth promoters has not so far been found effective in preventing the onset of winter dormancy. However, spraying with GA3 reduces slightly the period of winter dormancy and increases the first flush crop in some clones like TV1, TV7, TV9, TV15, TV18, etc. provided there is no other limiting factor. TV2 did not respond to the treatment and the first flush was found to start at its usual time. Degree of response also varied depending upon the environmental factors, mainly soil and atmospheric drought.

RATE OF LEAF UNFOLDING

Also called leaf period, it is the time gap between unfolding of two successive leaves. Small leaved chinary clones exhibit quicker rate of leaf unfolding than the broad leaved Assam hybrids. It also varies with the changes in climatic conditions. The average leaf period was found to be about five days during mid-summer (June-August) and increased to about nine days in November because of the changes in day length and ambient temperature. Importance of determining leaf period lies in deciding the duration of plucking round. Thus with five and nine days leaf periods as mentioned above, duration of plucking round should be 9(5x2-1) and 17(9x2-1) days respectively as per the formula worked out by Wight (1932). Therefore, instead of fixing the plucking round at 7-8 days uniformly as is more commonly done and recommended, it should preferably be based upon estimates of leaf periods made locally for each planting material.

Shade

Presence of moderate shade with recommended species is considered very important for the tea growing areas of plains of N.E. India. It reduces light intensity and leaf temperature, and also changes some of the physiological processes in a beneficial way which reflect on productivity. In one of the experiments with 35 per cent shade cover, transpiration dropped by 50 per cent and photosynthesis increased by 33 pe cent (Table 5). Shaded leaves also had more chlorophyll than the unshaded ones. Therefore, due importance must be given to have the right type of shade in tea growing areas.

Table 5. Rate of stomatal conductance (SC), transpiration (TR), photosynthesis (P_N) and total chlorophyll under shade (S^+) and no shade (S^-) conditions.

Clone	SC (mol $m^{-2} S^{-1}$)		TR (m mol $m^{-2} S^{-1}$)		Total Chl (MG G^{-1} fresh wt)		P_N (u mol $m^{-2} S^{-1}$)	
	S^-	S^+	S^-	S^+	S^-	S^+	S^-	S^+
TV1	0.470	0.317	10.54	4.89	2.51	3.44	6.73	9.28
TV20	0.502	0.258	9.76	4.45	2.41	2.94	5.96	7.58
TV18	0.579	0.435	11.72	5.65	2.26	2.73	7.28	9.10
TV25	0.452	0.286	10.18	5.17	2.65	3.58	6.07	8.64
Mean	0.501	0.324	10.55	5.04	2.46	3.17	6.51	8.65

HARVEST INDEX, PARTITION OF PHOTOSYNTHATES AND PRODUCTIVITY

The gross weight of a plant is the total weight of dry matter produced, i.e. the net weight plus the weight lost in respiration. The percentage of dry matter in the economically useful fraction of any plant (i.e. plucked shoots in case of tea) in relation to the gross weight of the entire plant is called 'harvest index'. In tea in plains of North East India its value generally varies between 9 to 12 per cent. In South India it has been reported to be around 14.7 per cent, possibly because of coarser plucking. Both these figures are much lower compared to those in other crops, for example in apple the harvest index being as high as 50 per cent. Per cent distribution of net weight, respiratory loss and net weight as per cent of gross weight in different plant organs in annually pruned tea are given in Table 6.

Table 6. Per cent distribution of net weight and respiratory loss in different plant organs in annually pruned tea*

Particulars	Plucking	Pruning	Frame	Root	Whole bush
Net weight as % of gross weight	10.6	17.6	4.9	3.1	36.2
Respiratory loss	3.2	57.3	2.2	1.1*	63.8
Total	13.88	74.9	7.1	4.2	100.0

* Mean of six clones representing erect, intermediate and flat leaf types both high and low yielding.

Thus only about 36 per cent of the total photosynthates produced go to different plant organs, the remaining 64 per cent being lost through respiration of which about 57 per cent is accounted by the pruning only. Table 7 gives the annual partition of net dry weight (also called biomass) in LP, DS and UP bushes.

Table 7. Annual partition of net dry biomass (%).

Pruning operation	Plucking	Pruning	Frame	Root
LP	22	59	11	8
DS	30	47	14	9
UP	39	35	16	10

A high harvest index does not necessarily mean high yield. But increasing the harvest index helps in reducing the inputs without reducing the yield. To achieve this it would be necessary to take steps which increase photosynthesis, reduce respiratory loss, mobilise food materials to new shoots, and reduce formation of non-productive plant parts. Some of the ways for increasing the harvest index, and hence yield are given below :

1. **Adopt pruning cycle of 3-5 years and introduce skiffing operations within the pruning cycle. This will reduce the weight of pruning litter, which is responsible for the loss of maximum dry matter through respiration.**

2. **Avoid very high bush frame by having HRP or MP when needed. This will not only increase the efficiency in plucking, but would also help in reducing respiratory losses by unproductive branches.**

3. **While plucking in growing season, leave small sized shoots on the table to be plucked during the next following round. Ideally the shoots plucked should be largest in size and consistent with the quality. Duration of plucking round should be decided based upon leaf period for the given situation.**

4. **Have suitable shade, which reduces the leaf temperature and respiratory losses, and increases the yield.**

5. **Keep the ground well mulched and do not allow removal of fine pruning litter from the field. This will increase the carbon dioxide concentration during decomposition and thereby increase photosynthesis, and also reduce photorespiration.**

6. **Avoid formation of knots and twiggy growth for maintaining uninterrupted sap movement.**

7. **Create conditions so that the chances of damage by drought, waterlogging, hail, disease, pest activity, etc. are reduced to minimum. All these should help in reducing respiratory losses and increasing the plucking point density.**

8. **Improve soil conditions favourable for plant growth so that a proper balance of growth promoters to growth inhibitors is maintained for maximum growth.**

9. **Use planting materials which are less flowering, since flowers and developing fruits also form a strong sink.**

10. **Maintenance foliage should be just sufficient, neither too less nor in excess. In standard janam plucking it has been found generally quite paying to add a layer of new foliage after every 9-12 months of plucking. This will help in increasing the shoot size and the harvest index.**

GROWTH REGULATORS

Effect on Yield

Plant can synthesize the phytohormones like auxins, cytokinins or gibberellins in optimum quantities for its normal growth provided agroclimatic conditions are conducive and cultural practices are in order. Therefore, if the plant is self sufficient in its production of endogenous growth hormones, exogenous application of these will not respond .Two products like Ergostim (5.0 % Acetylthioproline + 0.1% Folic acid) at rate of 1 ml/5 l and Multiplex Tea/Cofee Special (8.1% Zn, 2% Mn, 2% Mg, 0.5% B and 0.01% Mo) at rate of 2.5 ml/l, 3 rounds for early crop and 3 rounds for backend crop at monthly intervals yieded 2-7 per cent more crop comparing to Urea 2%, Zinc 1% or Urea 2% + Zinc 1% (Table 8).

Table 8. Effect of growth regulators on yield of fresh leaf under different pruning operations.

Growth regulators	Crop yield (Kg/Plot)			
	UP	LP	DS	Mean
Control	38.61	29.08	33.74	33.81
Urea 2%	40.18	31.53	39.17	36.96
Zinc sulphate (1%)	41.45	29.46	37.10	36.01
Urea (2%) + Zinc (1%)	42.76	29.97	38.13	36.95
Ergostim (1 ml/5 l)	44.00	33.77	41.31	39.69
Multiplex (2.5 ml/l)	43.46	33.14	40.85	39.15
C.D. at 5%	4.58	3.79	3.95	3.41

Effect on Lateral Promotion

For lateral promotion in young tea, chemical pruning was suggested through the Advisory Leaflet No.17 on the basis of some exploratory trials. But later on, in large scale trials it did not show consistent advantage over the normal process for bringing up of young tea. Hence the use of chemicals for lateral branching in tea is NOT advantageous over the conventional method.

TEA SEED PRODUCTION-SILVICULTURE AND CERTIFICATION

I. D. Singh and B. K. Konwar

Tea is propagated by seed as well as stem cutting. A seed population in tea is composed of a large number of genetically heterozygous genotypes. It is elastic and can be fitted into a wide range of enviromental and field conditions without much change in its over all performance.

SEED CULTIVARS

Tocklai has bred and released one polyclonal and 11 biclonal seed stocks. Of these, two stocks are exclusively meant for cultivation in Darjeeling and other hilly areas. The remaining nine biclonal stocks are for the plains of N.E. India. The polyclonal stock TS 203 was the first seed cultivar released by Tocklai. It could not become popular due to wide variability in its progeny populations. The characteristics of all the biclonal stocks are given in Table 1.

Table 1. Characteristics of Tocklai biclonal seed stocks.

Stock No.	Year of release	Parental combination	Characteristics
TS378**	1968	14/5/35* X14/6/28*	This is a cross between two China type clones with above average yield and good quality. It is fairly uniform in its growth with small leaves and shoots and has good tolerance to drought. TS378 is suitable primarily for orthodox manufacture.
TS379**	1989	14/5/35* X14/12/16*	TS379 is also a cross between two China type clones with fairly uniform growth habit and medium sized leaves and shoots. It is better than TS378 in yield, quality and tolerance to drought. It is primarily suitable for orthodox manufacture.
TS449	1970	19/29/13 X19/31/14* (TV1)	This is a cross between a light leaf clone (TV1) and a dark leaf Assam clone with above average yield and quality having fairly uniform growth habit and leaf size. It is suitable for both orthodox and CTC manufacture. TS449 is tolerant to drought and suitable for drought prone areas of Assam Valley, Dooars, Terai and Cachar.
TS450	1970	20/23/1 X 270/2/13* (TV2)	It is a hybrid combination between an Assam type (TV2) and a very vigorous Cambod type clone. Stock possesses high yield potential and above average cup-characters with suitablility for both CTC and orthodox manufacture. It is tolerant to drought.
TS397	1976	19/29/13 X 19/35/2* (TV1)	TS397 is a hybrid combination of TV1 and dark leaf Assam clone of above average yield and quality. It is fairly uniform in growth habit with suitability for both CTC and orthodox manufacture. Yield and quality are more or less similar to TS449. It is suitable for drought prone areas.

TS462	1980	19/29/13 X 124/48/8* (TV1)	It is a very vigorous stock, produced by crossing TV1 with a Cambod clone. Progenies are more or less similar to TS450 and possess higher yield potential with above average cup-characters than TS450. Stock is fairly tolerant to drought and suited for CTC and orthodox manufacture.
TS463	1984	19/29/13 X 107/14 (TV1)(TV19)	Like TS462 this stock has also been produced by crossing TV1 with another Cambod clone, TV19 and is quite vigorous like TS462 and TS450. Progenies are fairly uniform in growth habit with above average yield and quality and tolerance to drought. Stock is suitable for both CTC and orthodox manufacture.
TS464	1984	19/29/13 X 19/29/2* (TV1)	This stock, resulting from a cross between two high yielding, and high quality hybrid clones, is more or less similar to TS449 but with higher yield potential and above average cup-character. It is fairly tolerant to drought and suitable for drought prone areas of Assam Valley, Tripura, Dooars and Terai. Suited for both CTC and orthodox manufacture.
TS491	1989	19/29/13 X S3A1 (TV1)	TS491 is a hybrid between TV1 and a light leaf Assam clone with fairly uniform growth habit. It is a quality stock and suitable for both CTC and orthodox manufacture. Yield and quality are better than the popular commercial jats.
TS520	1992	107/14 X 468/3/13 (TV19) (TV20)	TS520 is a vigorous hybrid stock resulting from the cross between two high yielding clones TV19 and TV20. Its progenies are fairly uniform in growth and more or less similar in performance to TS462 but superior than TS449 and possess high yield potential with above average cup character. Stock is suitable for CTC and orthodox manufacture. It is fairly tolerant to drought.
TS506	1994	19/29/13 (TV1) X 19/22/4	TS506 is a hybrid stock resulting from a cross between TV1 and a Cambod clone. Its progenies are fairly uniform in growth habit and are quite similar in performance to TS462 and TS520 but much superior to TS449. Stock possesses high yield potential with above average cup quality and is suitable for both CTC and orthodox manufacture. Like TS462, it possesses good tolerance to pests/diseases and is likely to do well in drought prone areas.

* Generative clone - a clone used in hybridization to produce seed stocks but not grown as vegetative clone

** Recommended for cultivation in Darjeeling hills.

ESTABLISHMENT

Seed baris of approved stocks are established either by planting the pairs of generative clones or by grafting them on any vigorous jat or clonal root stock.

Planting Pattern and Spacing

Biclonal seed baris, either newly planted or converted from the old seed baris by means of grafting, are needed to be planted/grafted in proper design.

1. When both parents are seed bearers like TV1 and 19/31/14 (TS449), the respective clonal pairs of a particular stock are to be planted/grafted, as the case may be, alternately in each row as shown below :

```
X O X O X O X O
O X O X O X O X
X O X O X O X O   X = generative clone A
O X O X O X O X   O = generative clone B
X O X O X O X O
O X O X O X O X
```

2. When only one parent is seed bearer like 14/5/35 (TS 378), the planting pattern differs. In such case the female parent is the seed bearer, and so one male parent tree is surrounded by a few female trees in the ratio of 1:3 as shown below :

```
X X X X X X X
X O X O X O X
X X X X X X X   X = Generative clone A
X O X O X O X         (female)
X X X X X X X   O = Generative clone B
X O X O X O X         (male)
```

Except in TS378 where only female parent is seed bearer, in all other approved biclonal seed stocks both parents are seed bearers.

Planting design may be square or triangular. Triangular planting allows a large number of trees per hectare with consequently greater yields, atleast initially. Square planting makes the lay out of drains and planting of green crop rows simpler. It also facilitates in mechanical cultivation.

In biclonal seed baris with clones of equal seed bearing capacity, the most commonly adopted design is alternate planting of the clones in each row and in either direction.

Seeds are borne over the entire surface of a seed bearer. The initial spacing should be such that the trees at maturity do not overlap one another. The spacing may also vary with the type of seed trees used. The following spacings offer a rough guideline.

Spreading types : 5.5m x 5.5m (18' x 18') to 6.0m x 6.0m (20' x 20')

Erect types : 3.5m x 3.5m (12' x 12') to 4.5m x 4.5m (15'x 15')

Chinary types : 3m x 3m (10' x 10') to 3.5m x 3.5m to (12' x 12')

The estimated numbers of plants per hectare in commonly used spacings are given in Table 2.

Table 2. Number of seed bearers.

Spacing (m)	Square planting	Triangular planting
3.0	1111	1283
3.5	816	998
4.5	494	590
5.0	400	462
5.5	330	382

Soil

Seed bari plants require the same growing conditions as tea under plucking. A well drained sandy loam to loam soil with least effect of drought is ideally suited for seed baris. In case of marginal soils deep pits (120 to 150 cm) should be dug, all the boulders/gravels should be removed from the excavated soil, and good soil and some well decomposed cattle manure/ leaf compost should be added and mixed well before filling the pits. Allow at least 3-4 weeks for the soil to settle down in the pits before carrying out any planting. This will ensure deep root growth desirable for seed baris.

Isolation

Tea is a cross pollinated, self incompatible and entomophyllous plant. Pollination is effected by a small insect called pserphid which has a short flying range. It is, therefore, necessary to maintain adequate isolation from other teas to avoid undesirable outcrossing. Investigations on the possibility of scattering the pollen by wind revealed that the tea pollens are heavy and sticky in nature, a condition which is not favourable for carriage by wind. Amma and Harada (1955) in Japan also observed that only non-viable, dried up pollen grains are carried by wind. Therefore, seedbaris need not be isolated in remote places like in the past. If planted near other seed baris or sections of tea under longer pruning cycle, a thick barrier of tall growing grasses (e.g. Napier hybrid grass, Guatemala etc.) or other evergreen trees (e.g. *Acacia auriculiformis*, *Cassia siamea* etc.) should be planted between the seed baris or sections of tea to prevent large scale outcrossing as well as to improve the over all micro-climate of the seedbari. A minimum distance of about 10 metres should be left between the baris or the bari and sections of tea.

Planting

By direct planting : The young seed bearers should be treated like any nursery plants at the time of planting. Vigorously growing plants of the clonal pair may be selected in the nursery for establishing seed bari. Following planting, they should be allowed to grow undisturbed without any pruning/plucking operations.

By grafting : Existing vigorous seed baris of old jats, biclonal stocks or vigorous clonal sections could be used to establish new seed baris quickly by grafting. Seed bearers/bushes under plucking must be rested enough (3-4 months) before grafting. However, the seed bari to be converted should be in good health and vigour. Old and weak bushes fail to tolerate the shock of heavy cut required for grafting.

Cleft, bud, rind or composite method of grafting may be used for establishing seed baris. (For description of the methods see Two and A Bud, Vol. 15, 1968, pp 103-109; Vol.18, 1971, pp 22-24; Vol. 22, 1975, pp 68-71 and Vol 32, 1985, pp 17-20). Spacing of grafted seed bearers may be adjusted according to the old spacings between 4.5 to 6.0 metre apart.

Grafts require an extra care during first year or so. Generally graft junction remains a vulnerable point of damage by strong wind or storm. In such vulnerable areas, it is advisable (i) to grow a row of suitable trees as wind-break and (ii) to provide strong support to the trees, with a bamboo or wooden post firmly tying the top growth to it at a suitable height above the graft union.

Aftercare, isolation, wind barrier and other agricultural practices for the grafted seed baris remain the same as those of direct planted seed baris.

MANAGEMENT

The initial management of young seed bearers upto 3-4 years differs in no way from the usual field practices carried out in young tea fields except pruning/skiffing and plucking.

Manuring

The young seed bearers upto 4th year after planting should be manured with YTD mixture 2:1:2 in the same way as young tea, the dose per plant varying according to the spread of the trees as given in Table 3.

Table 3. Manuring of seed bari.

Average spread of trees, cm	2:1:3 NPK mixture g/tree	
30 cm (0 year)	20	To be applied in 4 splits
60 cm (+1 year)	90	
90 cm (+2 year)	190	
120 cm (+3 year)	340	
150 cm (+4 year)	530	

Mature trees should be manured with NPK 2:1:2 mixture @ 100 kg Nitrogen/ha per year in spring during April/May. The fertilizer may be applied in a ring till the seed trees become fully mature, and thereafter broadcast method may be followed leaving an area near the collar unmanured.

Pruning

Except under exceptional circumstances, pruning is not recommended. However, unwanted shoots which induce congestion should be removed/lopped regularly for better seed yield. All other dead branches/twigs should also be removed regularly. In case of exceptional difference in the height of clonal pairs, it would be beneficial to balance the height by lopping. Seed baris need not be dense. Adequate light and aeration should take place. About 30-40 per cent sunlight should fall on the ground in a diffused manner to get high seed yields. Hence, certain degree of pruning/lopping should be done as and when required to maintain above growing conditions in the seed bari. In case of a seed bari becoming unproductive, if required, it could be rejuvenated by heavy pruning (MP) as is practised in tea under plucking with all its associated cultural operations like lime wash, indopasting etc. Height of the cuts may be between 90-150 cm above the ground.

Water Management

More than 75 per cent of the flower bud initiation takes place during the extension growth of first and second flushes (March to June) and about 97 per cent of the flower bud initiation is completed by about end of September. Blossoming commences in early October, reaching its peak in November-December, and ends by about January. Most of the seeds are generally obtained from November-December blossom, which ripen by next October, thus taking almost 10 months time.

The period from November to May is very crucial for the fruit development. Moisture deficit at this stage may affect the seed yield considerably. Depending on the soil moisture status/rainfall, watering should be done judiciously in order to avoid dropping of flowers/seeds due to desiccation except during the period of flowering which may result in flower drop.

Seed baris should be kept well drained. Localized waterlogging, resulting in debility or death of trees, generally occurs due to depressions around the trees caused by constant cheeling for seed collection. Such depressions should be filled up regularly.

Cultivation

A light hoeing to control weeds and to break the hard crust is beneficial in heavy textured soils. Chemical weed control and spraying of insecticides should be undertaken during non-pollinating periods.

Prior to seed collection, the ground under each tree should be cleaned and levelled to facilitate seed collection. The cheeled soil and weeds may be used to form temporary 'bund', especially in hilly and slopy areas, to prevent the rolling of seeds too far When the harvesting of seed is over, such bunds should be flattened to avoid any localized waterlogging.

Green Cropping

It is useful in young seed baris for reducing the cost of cultivation and maintenance besides improving the tilth of the soil. Green crops like *Crotalaria anagyroides* and *Priotropis cytisoides* are to be preferred to Bogamedeloa (*Tephrosia candida*) or African medeloa (*T. vogelii*) as the latter are very susceptible to red rust and black rot.

It is desirable to plant the green crops in lines between the seed bearers. Alongwith these *Stylosanthes gracilis*, *Mimosa invisa* or *Calapogonium mucunoides* may be grown as cover crop to supress thatch and other weeds. However, it would be necessary to sickle it at regular intervals. Care should be taken against fire in droughty areas, especially when cover crops are grown in seed baris.

Pests and Diseases

Tea seed bug (*Poecilocoris latus*) is the most common pest in the seed baris. It punctures the developing fruits, thus causing damage to the seed which becomes 'starred' or floater. The pest can be easily controlled by hand collection, particularly during its last nymphal stage, from November to April. It could also be kept under control by spray of suitable pesticides.

Since tea is an insect pollinated plant (entomophyllous), it is desirable that adequate population of the pollinating insect, i.e. pserphid is maintained during flowering from September to December in the hills and October to January in the plains of N.E. India. It is, therefore, suggested that seed baris should not be sprayed with any pesticide during August to January. If required, spraying of pesticides may be done safely during February to July.

Black rot and thread blight are the two commonly occurring diseases in seed baris, especially when they become too congested and penetration of sunlight and air gets restricted. These could be controlled by thinning out the seed bearers. In case of severe attack, two rounds of spraying from mid April to end May of 0.25 per cent solution of copper fungicide thoroughly on both sides of the leaves (against Black rot) and on stumps and twigs of the trees (against Thread blight) give good control.

Seed Handling

Tea seed is recalcitrant, i.e. it loses its viability upon drying. Hence, it must be handled carefully so as not to be allowed to dry once it falls on the ground till it is sown.

Generally seeds start dropping from end September and it continues upto early January. Peak dropping is during late October to late November depending on the prevailing temperature. Seeds should be preferably collected everyday from clean ground and stored in moist sand beds under shade. Such collected seeds should be graded for floaters and for very small and damaged seeds which are rejected before sowing/packing.

Sorting of seeds of the biclonal stocks into different size grades is not recommended as it will affect the composition of hybrid progenies in the plantation. However, screening may be undertaken to eliminate only those extremely small seeds which are found below the characteristics of the stock.

Since there is no dormancy in tea seed, it can be sown immediately after cracking of the seed coat or even after collection. If needed, seed can be stored at low temperature of $5^{\circ} \pm 1^{\circ}C$ in cold storage safely upto one year. To protect the seeds from any fungal attack, treatment with 0.1 per cent mercury chloride by way of dipping the seeds in the solution for 15 minutes, then washing with water and surface drying before packing or sowing are suggested.

Packing is generally done in wooden boxes of standard size with net content of 20 kg seed. The usual method of packing is to place a sheet of firm brown paper along the bottom of the box. On this a layer of the packing medium (charcoal powder/sand/sub-soil/ash) is sprinkled and then a layer of seeds (one seed thick) is placed. This seed layer is then covered with a thin layer of packing medium and covered again with another sheet of brown paper. This process is repeated until the box is full. A sheet of brown paper is then laid on the top and the lid is nailed down. For cold storage, seeds may be packed in polythene lined hessian bags.

The moisture content of the packing material used varies from 10-12 per cent in sand and ashes to 20-30 per cent in charcoal powder.

If seed is required to be stored at room temperature, it should be done in bins or pits in a cool shade in moist sand or sub-soil for as short a time as possible. The moisture content in the sand or sub-soil should not exceed 10-12 per cent. Such stored seeds should be put to floater/sinker test before packing. Ensure use of clean water for conducting floater/sinker test.

Shelf life of tea seeds can be also increased by treatment with 0.5 per cent Jalshakti (a starch polymer), followed by storage in polythene lined hesian bags at room temperature.

The testing of seeds against cheesy, starred or damaged seeds should be done regularly before packing to ensure the seed quality.

SEED YIELD

The yield of tea seeds varies considerably from region to region and from seed bari to seed bari within the region. It is influenced by the factors like growth of the seed bearers, extent of moisture stress during the fruit and seed development, extent of seed bug damage, adequacy of pollination, synchronization of flowering of both the parents and level of maintenance. Generally yields are low in droughty areas and may range between 0.5 kg to 1.5 kg per seed bearer per year. In good tea growing areas, like Upper Assam, it may range between 1.5 to 3.5 kg per bearer per year at maturity, usually from 5th year onward. Seed yields of biclonal stocks upto 4 kg in Dooars/Terai and 8 kg per bearer in Upper Assam have been recorded. Table 4 shows yield progression of seed baris in N. E. India which is based on a survey of about 20-25 seed baris.

Table 4. Yield progression in seed baris, kg/seed bearer.

Year after planting	Normal growing conditions	Droughty areas
3rd	0.3 - 0.5	0.1 - 0.2
4th	0.5 - 0.7	0.2 - 0.3
5th	0.7 - 1.0	0.3 - 0.5
6th	1.5 - 2.0	0.5 - 0.7
7th	2.0 - 2.5	0.7 - 1.0
8th	2.5 - 3.0	1.0 - 1.5

SEED CERTIFICATION

TRA has laid down certain rules for the seed production of Tocklai approved biclonal seed stocks to ensure quality production of seeds, and to prevent entry of spurious seeds in the industry. The rules are quoted below :

1. Generative clone of the stock will be supplied free of cost to the growers. In case one of the parents is an already available TV clone, only the other generative clone(s) will be supplied free.

2. The TRA member seed growers will be charged Rs. 10.00 per seed bearer per year as royalty from 5th year after planting, when the trees come into bearing, until the seed bari is uprooted or abandoned. The producers of Tocklai approved seed stocks are required to inform TRA of any change in the status/ particulars of the seed bari promptly.

3. The seed bari should be planted and maintained according to the approved design supplied by TRA.

4. While marketing seed, growers are to follow the following pattern in describing the seed.

   (a) Estate's name or other identification of the grower, followed by

   (b) Tocklai (biclonal) stock number. e.g. "Heeleakah Tocklai biclonal stock 462".

6. The names of TRA member seed growers, who fulfil the above conditions and the description of their seed, will be published from time to time free of chargs in Two & A Bud. The names of the growers who fail to fulfil the above conditions will not be published.

7. Tocklai will issue certificate valid for three years only to the approved producer of biclonal stocks. TRA reserves the right to withdraw certificate from any producer(s) not following the rules laid down by TRA.

8. The producers are requested to note the date of expiry of the certificate(s) and intimate Tocklai well ahead of time. Fresh certificate(s) will be issued on receiving the intimations on the basis of satisfactory report from the representative of the Director.

9. Any change in number of seed bearers made or caused naturally, or the seed bari(s) uprooted wholly or partly, should be intimated to Tocklai immediately to update the records. Tocklai reserves the right not to entertain any dispute in the number of seed bearers, once the bill for royalty has been raised.

Following information needs to be furnished to Tocklai for the recognition and certification of the seed bari through Advisory Officer of the respective zone as soon as the seed bari comes into production :

1. Seed stock
2. Date of planting the seed bari
3. Source of the planting material
4. Total area in hectare
5. Spacing and design
6. Total number of trees
7. Production of saleable seeds (seasonwise)
8. Isolation distance in all directions from other teas
9. Present status of the seed bari

SALIENT FEATURES FOR RAISING A SUCCESSFUL TEA NURSERY

B. Borthakur and M. K. Banerjee

INTRODUCTION

Tea was propagated only through seeds till the middle of this century. The possibility of raising tea plants from single node cuttings as an economic method of vegetative propagation was first reported by A. C. Tunstall from Tocklai in 1931. Thereafter it took about 18 years to standardize the technique of vegetative propagation and it was only in 1949 that the first set of three clones was released to the industry. Since then vegetative propagation has successfully been employed for multiplication of tea. However, seed propagation has to continue side by side in its own merit with high yielding seed stocks.

ESTABLISHMENT OF NUCLEUS PLOT

1. The nucleus plot of tea bushes (mother bushes) from which cuttings are to be taken should be established at a convenient place.
2. The soil should be fertile and well drained.
3. In order to make the bushes hardy, shade planting is not necessary in nucleus area.
4. Existing nucleus or any other tea areas can be converted to new clonal nucleus plot by cleft or bud grafting. This is a quick method for establishment of a new clone.

Care of Mother Bushes

In order to obtain healthy cuttings for quicker growth in the nursery it is essential to protect the mother bushes from pests and diseases. The latter are often carried to the nursery from the mother bushes.

Pruning/Skiffing of Mother Bushes

In general, two periods of vegetative propagation are recommended :

April/May	: Spring propagation
September/October/November	: Autumn propagation

For spring propagation, the mother bushes should be pruned as per the schedule given in Table 1, and cleaned out in mid October to early February. For autumn propagation they should be deep skiffed in June/July leaving about 12 cm of new wood.

The time of pruning/skiffing can be staggered by 10-15 days in batches to ensure supply of good cuttings for extended propagation.

Table 1. Effect of time of pruning/skiffing on availability of cuttings.

Time of pruning/skiffing	Approximate time by which primary cuttings will be available
Time of pruning	
Mid Oct to 1st week of Nov	End Apr to early Jun
Mid Nov to 1st week of Dec	Mid May to end Jun
Jan to early Feb	Jun to Jul
Time of deep skiffing	
Early Jun	Sep to Oct
Early Jul	Oct to Nov

Manuring of Mother Bushes

Mother bushes upto the age of five years should be manured with split application of NPK (2:1:3) mixture as applicable for manuring of young tea.

Mature mother bushes should be fertilized with NPK (2:1:3) mixture at the rate of 140-150kg N/ha. Half the quantity of mixture may be applied to the moist soil during March-April and the balance half after regrowth following pruning/skiffing for autumn propagation (July/August). The nitrogen level may, however, be reduced by 20-30 kg/ha when cuttings are taken only once in a season.

TYPE OF CUTTINGS.

1. Cuttings should preferably be taken from the primaries with dormant apical buds (banjhi stage). Success is generally higher from such cuttings.

2. In some clones, lateral shoots are thrown out from the lower portion of the primaries quite early. In such cases, the unbranched portion of the primaries should be taken first, and then the laterals when they mature after a few weeks.

3. A good cutting should have a fully mature healthy undamaged leaf, dormant or just swelling bud and a hard green stem of about 2.5 cm in length below the leaf and around 0.5 cm above the leaf.

NURSERY BEDS AND SHADE

1. Nursery beds should be East-West oriented under overhead shade. In East-West beds the North side should be left open for better air circulation and penetration of light. The Northern height of shades should not be more than 180 cm and should slope down towards South by 60 cm.

2. Bamboo lath frame and thatch are suitable materials for shading nurseries.

3. Beds under low shade should be North-South oriented. Shade is provided by putting bamboo lath frame at about 22.5 cm over the propagation beds, supported by side walls. The lath frame should be gradually raised with increase in height of the plants.

4. It is necessary to prepare the beds at least 6-8 weeks before planting cuttings. Shade should be provided immediately after preparation of the beds. It is better to avoid periods of heavy rain for preparation of beds as clods are difficult to break when the soil is wet.

5. The width of the nursery bed is generally limited to 120 cm but it can be of any convenient length.

6. Each bed should be enclosed by a drain of about 45 cm deep and 30 cm wide. These drains should run into one or more good outlet drains.

7. The surface of the beds should be slightly cambered for quick run-off of rain or irrigated water. The soil on the beds must be firm but not very hard.

8. Application of single super phosphate @ 0.5 kg/m^3 of soil used for filling sleeves or 50g/sq m of bed helps in better root development. In beds the phosphatic fertilizer should be incorporated into the soil to a depth of 15-20 cm at the time of soil preparation.

USE OF POLYTHENE TENT UNDER OVERHEAD SHADE

In Darjeeling and other places where winter temperature falls very low, a polythene tent may be provided over each bed under overhead shade to create optimum temperature and conserve moisture required for good growth of the cuttings.

The tent may be erected about 45 cm above the cuttings and semi circular bamboo frames may be used to support polythene sheets over the beds. The polythene sheets should be sealed on all sides of the bed by using soil at the bed level.

TYPE OF SOIL

1. Soil should be neither too sandy nor too clayey.

2. The acidity status of the soil should be between pH 4.5 and 5.0.

3. If the soil is too acidic (pH below 4.5), add slaked lime to the soil at the rate of 2 t/ha. Sub-acidic soils (pH above 5.1) can be corrected by treating with 2 per cent aluminium sulphate solution repeated for 2/3 times, if necessary. Soil should be retested for acidity before planting cuttings. If possible, soil with pH above 5.5 should be rejected.

4. In case of heavy soil its physical conditions can be improved by mixing some coarse sand. It is necessary to check the pH of the sand-soil mixture after mixing.

5. As far as possible the soil should be free from parasitic eelworm. Soil having an eelworm count of lesser than four/10 g of soil can be used. However, such soil should be treated with Furadan @ 2 g/sleeve in two doses at monthly interval.

6. Experiments indicated that sub-soils upto a depth of 90 cm can be used with the addition of well decomposed organic matter or cattle manure at the proportion of 1 part organic manure : 5 parts sub-soil. If the sub-soil is found to be of heavy texture, sand should be mixed with the soil at proportions already suggested.

POLYTHENE SLEEVE NURSERY

Cuttings can be planted directly into the sleeves.

Sleeve Size

Sleeve of the size 15 cm lay flat (6"), 22 cm long (9") and 150 gauge thick ensures a healthy plant. Sleeve of smaller size produces weak plant.

Filling of Sleeves

1. Filling of sleeves should be completed 6-8 weeks prior to planting of cuttings/seeds.

2. Before filling the sleeves, the soil should be sieved through No.4 wire mesh (i.e. 4 holes/linear inch) to eliminate undecomposed organic matter and pebbles.

Planting of Cuttings

1. Cuttings should be firmly planted in the soil. To avoid bark splitting and air pockets at the interspace of cuttings and soil, dibber must be used. The dibber should be slightly thinner and the hole made by it be shorter than the cuttings.

2. Care should be taken to keep the petiole above the soil surface to avoid rotting of the mother leaf. The mother leaf should be more or less in an upright position after insertion.

3. Dip the cuttings in 0.1 per cent zinc sulphate solution before planting. This helps in root initiation.

4. In rooting beds when "Fish scale" method is used to accommodate large number of cuttings, they should be transferred to sleeves just after initiation of roots.

Over shading leading to accumulation of excess moisture in the soil and pH higher than 5.0 may cause excessive callus formation at the expense of the root growth. Maintenance of the soil moisture at field capacity is important.

Thinning of Shade

Heavy shading affects the growth of cuttings adversely. Shade should be such as to cut about 50 per cent light falling on the nursery bed in form of sunflecks. In low lath frame shade the bamboo frames should be raised on the East gradually after the cuttings have produced 4-5 new leaves. With overhead shade, where thatch is used, automatic thinning occurs in time. When bamboo lath is used, gradual removal of the roof (alternate one) ensures adequate hardening of plants. The plants should be kept outside without shade for a couple of weeks before taking them to the field.

TEA SEED NURSERY

The procedure for preparing beds and sleeves for planting seeds is the same as with V.P. nursery.

Shading

It is necessary to protect the seedlings from excessive heat and hail storm by providing thin shade on them. This can be done either by growing green crop like *Crotalaria anagyroides* in between the beds or by providing an overhead shade. In areas subject to hot winds, it is essential to protect the nursery area by establishing a wind break by growing fast growing evergreen trees like *Cassia siamea, Acacia auriculiformis* etc or Guatemala grass.

Planting of Seeds

1. Tea seed loses its viability rapidly; therefore, the seeds must be sown as soon as possible after harvesting.
2. Pre-germinated seeds should be used. It facilitates uniform nursery.
3. Seed should be sown at a depth of about 2.5 cm with the 'eye' (micropyle) pointing downwards.
4. After sowing the seeds, the beds or sleeves should be covered with a thin layer of mulch (cut grasses, leaves of green crop, etc.).
5. The soil of the nursery beds should remain moist. Watering should be done as and when required just to moisten the soil. Excess watering should be avoided.

AFTER CARE OF NURSERY

1. Regulation of shade is necessary where overhead shade is provided. Too early or sudden removal of shade may damage the young plants while delayed exposure results in weaker growth.
2. Weeding of the nurseries should be done by hand whenever necessary.
3. Young plants should be protected from pests and diseases by spraying suitable pesticides using high volume sprayer.
4. When the plants have produced 3/4 leaves they may be manured with a mixture of NPK (2:1:2) and sand at 1:9 ratio. One tea spoonful of this mixture should be applied per plant at 3-4 weeks intervals for about 10-12 times during the growing season, if required.
5. Foliar application of nutrients can be started when the cuttings produce 6-8 leaves. It should preferably be done during the morning hours in the months of April-May and August-November. The concentration of various nutrients in the spray fluid is suggested below :

NPK (2:1:2)	-	0.50 per cent
Zinc sulphate	-	0.10
Borax or boric acid	-	0.05
Ammonium molybdate	-	0.05
Magnesium sulphate	-	0.30
	Total	1.00

MINERAL NUTRITION IN TEA FOR NORTH EAST INDIA

J. Chakravartee and M. P. Sinha

If machine brought revolution in augmenting productivity in the field of agriculture as in some countries, chemicals worked miracle over a larger horizon - much more than one can usually perceive. Among the chemicals used in agriculture such as fertilizers, growth promoters, herbicides, pesticides and most of others in direct and indirect use, fertilizers stand out prominently as a class by itself, most universal in application and potent in efficacy. It wrests the full benefit that irrigation, drainage and other field practices contribute to the crops. Tea is no exception to this. Judicious use of fertilizers makes possible sustained increased production of tea over a long period and does not pose unnecessary problems of soil exhaustion.

ESSENTIAL PLANT NUTRIENTS

Sixteen nutrient elements are recognised at present as being essential to all plants for their normal growth and development. Of these, carbon (C), hydrogen (H) and oxygen (O) make up bulk of the plant tissue and are derived from air and soil water. The main source of carbon is carbon dioxide (CO_2) in the atmosphere and its concentration in the vicinity of the tea bush is around 0.03 per cent.

The remaining 13 nutrients are derived from the soil and are grouped as major, secondary and trace elements according to their requirements by plants for normal growth and development. Nitrogen, phosphorous and potassium are used in large quantities and are called major or primary nutrients, while calcium, magnesium and sulphur are required in relatively smaller but in appreciable quantities and are known as secondary elements. The remaining seven nutrients viz. iron, zinc, manganese, copper, boron, molybdenum and chlorine are required in small quantities and are referred to as micronutrients or trace elements. In addition to these, aluminium and silicon are also found in the tea plant. The role of these two nutrients in plant metabolism is still not clear. However, silicon is well known now for its oxidising power in soil and making native phosphate easily available.

Each of the essential nutrients has a definite and specific function to perform in the growth and development of plants. A deficiency of any of the nutrients can be a limiting factor for proper growth, development and yield.

AVAILABILITY OF NUTRIENTS

A productive soil should contain all the essential plant nutrients in sufficient quantities and in balanced proportions. The nutrients should also be present in an available form before plants can use them. Total content of a nutrient in the soil profile can often be a poor guide of its availability to plants. A fraction of these nutrients exists in the soil solution in forms which can be readily absorbed by the plant roots. The availability of nutrients in the soil is governed by soil properties and it differs from soil to soil.

Physical Factors

Physical properties of the soil like texture, structure, clay minerals and soil colloids (organic matter or clay) largely determine the availability of inherent or applied nutrients. A well developed root system can only ensure maximum utilization of nutrients. Poor soil conditions like poor structure, inadequate drainage conditions, etc. which restrict root development need to be attended first for making a fertilizer policy economic and efficient.

Chemical Factors

Soil pH indicates the acidity or alkalinity of soil. Soil pH is defined as the negative logarithm of hydrogen ion concentration. Thus, each unit change in soil pH means a tenfold change in the amount of acidity or alkalinity. Availability of nutrients like N, Ca, Mg, P, K and S decreases when pH goes down below 6.0. However, tea grows well when soil pH ranges between 4.5 and 5.5. Microbial activity in the soil is also at its optimum above pH 5.5. The organic colloids and clay particles of the soil are most reactive components and are characterised by a high surface charge (negative) and a large specific surface. Positively charged nutrient ions ($NH4^+$, Ca^{++}, Mg^{++}, K^+, Fe^{++}, Cu^{++} and Zn^{++}) are attracted by the negative charge of the soil colloid. The total number of exchangeable cations a soil can hold is known as the cation exchange capacity (CEC). Hydrogen ion (H^+) has got the highest affinity for absorption and in the acidic range of soil pH the CEC is always low. The chemical properties of the tea soils have also undergone considerable changes due to prolonged use. Intensive leaching along with continued use of

acid forming fertilizers (e.g. SOA and urea) have rendered most of the tea soils considerably acidic (pH 3.0 - 4.5) resulting in low exchange capacity and loss of structure. Liming under such a situation can improve the structure and chemical properties of soil including retentive capacity for many nutrients (particularly cations).

Biological Factors

The fertility status of a soil largely depends upon the activity of the microorganisms. The useful microorganisms decompose organic matter and make nutrients available in simpler forms for use by the plants. Conversion of fertilizers like urea is also brought about by the microorganisms present in the soil before they can be utilized by the plants. The microorganisms population undergoes considerable change in cultivated soils and under monoculture like tea, many beneficial species prevalent in the original forest floor conditions disappear with the progress of time. In addition, the organic matter degradation is much rapid under the humid subtropical climatic conditions of tea growing areas, and with very little recycling of organic matter (lack of preservation efforts of pruning litter as well as diminishing shade stand) the biological activity deteriorates fast. The normal restorative practice of crop rotation is not feasible in tea cultivation and hence organic matter management assumes greater significance for optimum response from added fertilizers. This aspect will be dealt under "Soil Management in Tea".

Plant Factors

Plants differ in their adaptability to soil reaction. Many of the principal crops (e.g. wheat, barley, tobacco, etc.) and vegetables are sensitive to acid soils and suffer injury when grown in those soils. Certain crops (e.g. rice, beans, tea, etc.) on the other hand tolerate acidity fairly well. In fact, tea grows well when the pH ranges between 4.5 and 5.5, a range at which availability of most nutrients is not favourable. In addition, the cation exchange capacity of the root system also influences the uptake and preference for nutrients. The tea plant is also known to be an accumulator of aluminium with 5,000 - 16,000 ppm in the mature leaves, which is rare with other plants.

Plant roots absorb the nutrients present in the soil solution. Provided that the soil mass is thoroughly filled by active roots, a plant has greater opportunity to use the readily available sources of nutrients. The plant itself can, therefore, influence the availability of nutrients and their exploitation. A deep root system has a greater chance in exploiting nutrients leached down, in addition to exploitation of a greater depth of soil profile.

SOIL FERTILITY AND CROP PRODUCTIVITY

The fertility status of cultivated soils declines with progress of time affecting crop productivity. Experience has shown that as soon as a soil is brought under cultivation after cleaning the forest growth, the organic matter fraction undergoes rapid degradation, and most cultivated soils show a 30-40 per cent decline in the organic matter level within a short period (20-30 years) of time. However, recycling of organic matter in the form of crop residues is a natural process of husbandry in cultivated soils and puts a check on unabated depletion of the organic matter status. Long term conservation of soil fertility is, therefore, related with preservation of organic matter. In a monoculture like tea, natural leaf fall, pruning and skiffing litters as well as shade tree droppings have good conservation potential.

Experience has also shown that no cultivated soil can supply the nutrients in sufficient quantity beyond a point of time depending upon the original fertility status, intensity of cultivation and climatic conditions. Without supplementing nutrients by way of fertilizer application, it is impossible to maintain yields at economic levels beyond short periods.

A well conceived soil and fertilizer management system can only bring about an equilibrium between the degenerative and restorative activities in the soil environment. Depletion of nutrient reserve in tea soil profile can be prevented by a rational fertilizer use programme. A good level of organic matter is also important to obtain the optimum benefit from fertilizer inputs.

FERTILIZER AND CROP PRODUCTIVITY

Two important natural laws, viz. law of limiting factor and law of diminishing return govern the response of a nutrient. The former law signifies that normal growth activity can be resumed only after removal of limitation imposed by restricted supply of particular nutrient(s), while the latter defines that response in term of economic yield decreases with increasing level of supply of a nutrient and beyond a certain point the response becomes negative. The shape of the response curve can also be influenced by climatic changes, bush management practices as well as factors like soil type, planting material, irrigation and possibly age. Young teas can show a different response curve than that of mature teas, since in the former large proportion of absorbed nutrients is utilized for development of frame and root system, whereas in the latter it contributes mainly to the crop. The critical point in the response curve (i.e. the point beyond which response becomes negative) in economic term is influenced by market cost and return changes, and cannot be fixed by biological definition. An assessment of the relationship

between fertilizer and crop productivity in the field is hence important. Studies on utilisation of fertilizers for crop promotion have shown that inspite of advancement of research, fertilizer use efficiency has generally remained low and a recovery of about half of the applied nutrient is considered to be good. Loss in drainage water accounts for some of the readily available nutrients like nitrate 'N' and potassium, while chemical reactions with Fe, Al or Ca can render some phosphorus unavailable.

PREDICTION OF FERTILIZER NEEDS

There are two ways to predict fertilizer needs, viz. deductive and inductive approach. In the former, field experimental data from a large number of diverse soils are pooled for the purpose of soil test and crop response correlations. In the inductive approach soil test and crop response studies are carried out on some soils under same agro-climatic conditions and management. The two approaches essentially differ in that the former attempts at averaging the results under diverse situations and has a wider application, while the latter seeks site specific information and extends it to similar situations.

It is necessary to examine periodically the changes in the status of various nutrients and by a careful examination of the field at specific time over the pruning cycle. It should be possible to determine potential deficiencies before they occur to take remedial measures preventing acute deficiency and cause serious shortfall in yield. Hence, it is better to take soil samples at the same time each year for consistency, and also leaf samples if necessary.

FERTILIZER SOURCES

The nutrient contents of some commonly used fertilizers are given in Table 1.

Table 1. Fertilizers and their nutrient contents.

Table 1. Fertilizers and their nutrient contents.

Name of Fertilizer	Nutrient content (%)
Ammonium sulphate	N - 20.6, S-24
Ammonium sulphate nitrate	N - 26, S-15
Urea	N - 46
Ammonium phosphate	N - 20, P_2O_5-20
Di-ammonium phosphate	N - 18, P_2O_5-46
Single super phosphate	P_2O_5 - 16, S-11.9
Triple super phosphate	P_2O_5 - 43
Dicalcium phosphate	P_2O_5 - 42(acid soluble)
Rock phosphate	P_2O_5 - 20 to 24(acid soluble) S-2.3
Muriate of potash	K_2O - 60
Potassium sulphate	K_2O -50, S-11 to 18
Zinc sulphate	Zn - 23 to 35, S-11 to 18
Zinc chelate	Zn - 9 to 14
Magnesium sulphate	Mg - 9.88, S-13
Potassium schoenite	Mg - 11, K_2O-22, S to 22
Manganese sulphate	Mn - 26 to 28, S-15 to 17
Borax	B - 11.3
Boric acid	B - 17
Molybdic acid	Mo - 40
Gypsum	S - 18
Phosphogypsum	S - 14, Ca-18, P_2O_5-1
Pyrites	S - 22 to 24
Sulfex	S - 80

FERTILIZER MANAGEMENT FOR YOUNG AND MATURE TEA

The fertilizer policy for young tea should be different from that of mature tea, as development of a strong frame and root system can only support vigorous cropping at maturity.

Made tea contains approx. 5 per cent N, 1 per cent P_2O_5 and 2 per cent K_2O. An average crop of 2000 kg/ha (over a cycle) will remove around 100 kg N, 20 Kg P_2O_5 and 40 kg K_2O per ha per annum in addition to a large amount of nutrients being locked in the bush frames; a part of which is, however, returned to the soil through recycling of pruning litter. In formulating a fertilizer

policy for mature teas, these high removals as well as low nutrient retention capacity of tea soils and the low fertilizer efficiency should always be kept in view. Preservation of pruning litter (approx. 2000 kg/ha/year) can contribute positively in maintaining the fertility status as well as optimising fertilizer use since approx. 40 kg N, 20 kg P_2O_5 and 30 kg K_2O are expected to be recycled through pruning litter.

Manuring at Planting Time

No inorganic fertilizer except phosphate is recommended at the time of planting young tea. The best manure for planting pit is well rotted and friable cattle manure or compost. About 3 to 5 kg of well rotted organic manure should be used per pit. In absence of sufficient quantity of bulky organic manure, concentrated organic manure like oil cake at the rate of 150-200 g per pit can also be used as a substitute. Concentrated organic manure should be thoroughly mixed with the excavated soil. A fresh stock of oil cake should be fermented by exposing to atmosphere with adequate watering to avoid injury to the root system.

The present recommendation of phosphatic fertilizer is 30 g each of single super phosphate and rock phosphate per planting pit. The rock phosphate should be evenly mixed with the loosened bottom soil for gradual availability while the super phosphate should be placed around the bheti at about 5 cm below the ground surface.

Manuring of Young Teas

Adequate fertiliser application during initial years for sustaining high level of productivity has been confirmed by large number of field experiments. A 10:5:10 YTD mixture (10 kg N, 5 kg P_2O_5 and 10 kg K_2O per 100 kg mixture) is recommended during the formative stage. In case the level of available potash is below 100 ppm, a 10:5:15 mixture is preferable.

The root system in young tea being under continuous development, frequent application in small quantities is advisable till the plants cover the ground fully. Four applications at 6-8 weeks interval are normally suggested during 0, 1, 2 and 3 years. In 4th and 5th years two equal applications (strip method) are suggested.

The revised recommendation on manuring of young tea is given below in Table 2.

Table 2. N level for young tea (as 10:5:10 or 10:5:15 NPK mixture) during formative stage (0-4 years).

Year from planting	N kg/ha	YTD kg/ha	Method of application
0 Year	20 - 40	200 - 400	Ring in 4 splits
+ 1 Year	80 - 100	800 - 1000	Ring in 4 splits
+ 2 Year	100 - 120	1000 - 1200	Ring in 4 splits
+ 3 Year	120 - 140	1200 - 1400	Ring in 4 splits
+ 4 Year	140 - 150	1400 - 1500	Strip in 2 splits
+ 5 Year	140 - 150	1400 - 1500	Strip in 2 splits

Response in terms of vegetative growth is recorded to increased dosage of nitrogen by about 15 per cent in the first three years after planting.

Manuring of Mature Teas

To maintain the health of tea bushes and to obtain high yield the soil must be replete with essential elements. A series of fertilizer experiments conducted during 1970-90 under different agroclimatic conditions in N.E. India have indicated a response not only to nitrogen but also to annual application of phosphorus and potash. Results from the crop response curves indicated that annual application of balanced dose of NPK is needed to harvest maximum crop. For sustaining a yield of about 23 q/ha in different regions, generally a dose of nitrogen not exceeding 140 kg, phosphate between 20-50 kg and potash not exceeding 140 kg would suffice. These experimental findings are largely corroborated by the results of the survey data collected recently from the estates of the Assam Valley. In about 80 per cent of the surveyed area where the productivity was between 25-30 q/ha, the above level of NPK was found to be optimum. Possibility of sustaining a productivity level as high as 35 q/ha or more by marginal increase of the nitrogen level above 165 kg alongwith phosphate and potash at 50 kg P_2O_5 and 165 kg K_2O respectively was also indicated from these data.

The activity of the enzymes like nitrate reductase, glutamate dehydrogenase, glutamine oxo glutarate amino transferase and acid phosphatase was found to be increased at phosphate level upto 50 kg P_2O_5/ha with 150 and 200 kg N and 150 kg K_2O. The uptake of nitrogen and the synthesis of protein were maximum at this dose of phosphorus under the field conditions studied.

In the presence of nitrogen and phosphate, a positive response was recorded from applied potash upto 150 kg K_2O/ha every year. The depletion of exchangeable potash was found to the extent of 45 per cent at the end of the cropping season indicating the need of regular potash manuring for sustained high yield. Enhanced levels of K_2O corresponding to high levels of N could contribute more towards yield in vigorous teas.

The current recommendation on nutrition of mature tea is given in Table 3.

Table 3. Recommendation on NPK manuring in mature tea for plain districts of North East India.

Yield range in KMTH (cycle average)	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha Soil available potash status Low1	Medium2	High3
Upto 1500	Upto 90	20	Upto 90	Upto 70	Upto 50
1500-2000	90-110	20-30	90-110	70-80	50-70
2000-2500	110-140	30-50	110-140	80-120	70-100
2500-3000	140-165	50	140-165	120-140	100-120

1. Lesser than 60 ppm 2. 60-100 ppm 3. Higher than 100 ppm

The agro-climatic conditions of Darjeeling estates are different from those of plains estates. With a comparative low yield potential but quality product and slow decomposition process of organic matter, the highest level of N should not exceed 110-120 kg N/ha. Table 4 gives the recommendation for NPK nutrition of mature tea in Darjeeling region.

Table 4. Recommendation on NPK manuring in mature tea in Darjeeling region.

Yield range in KMTH (cycle average)	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha Soil available potash status Low1	Medium2	High3
Upto 600	Upto 60	20	Upto 60	Upto 50	Upto 35
600-1000	60-90	20	60-90	50-70	35-50
1000-1400	90-120	20	90-120	70-100	50-70

1. Lesser than 60 ppm 2. 60-100 ppm 3. Higher than 100 ppm

METHOD OF FERTILIZER APPLICATION

Uniformity of application is vitally important for optimum results. For application of small quantities of fertilizers as done in Darjeeling as well as with young teas, ring application is expected to ensure greater uniformity compared to broadcast method of application.

Field experiments on split application have not recorded universal response. However, studies showed that nitrogen availability starts after two weeks of fertilizer application. Peak uptake of nitrate (NO_3) is after 5-16 weeks of fertilizer application but its absorption by the plant continues for about four to five months. This knowledge leads us to suggest that where dose exceeds 100 kg N/ha, splitting of nitrogen into two to three doses at an interval of 3-4 months in 60:40 or 40:30:30 ratio will improve fertilizer use efficiency. Leaching loss is also reduced by split application. Split application of potash is of special importance where the soil is coarse textured and has low retention capacity for the nutrient.

SECONDARY NUTRITIONAL ELEMENTS

Calcium and magnesium requirements are fulfilled to a great extent by maintaining the soil pH between 4.5 to 5.5. With large scale introduction of high yielding Cambod clones, magnesium nutrition has assumed greater significance. Foliar spraying of magnesium sulphate at 1 to 2 per cent (w/v) concentration between autumn and spring (October to March) helps to prevent manifestation of deficiency symptoms.

Sulphur is important for the synthesis of proteins and vitamins. Photosynthesis and carbohydrate metabolism are adversely affected when sulfur is deficient in the plant. The sulfur uptake by tea from well drained and well aerated soil is in the form of sulphate (SO_4) present in the soil solution and the sulphate absorbed on soil colloids. These two together comprise the available sulfur for plant.

Sulfur mineralisation - immobilisation picture has been presented in Fig. 1.

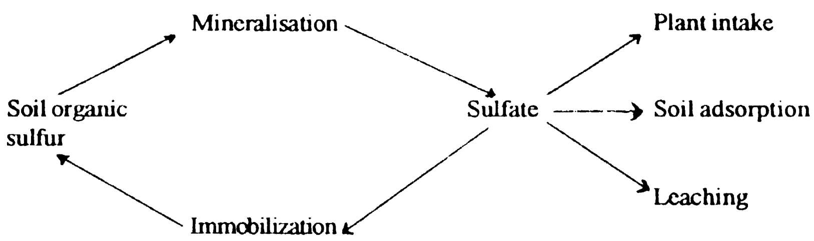


Fig. 1. Mineralisation - immobilization of soil sulfur.

Soil sulfur reserve is likely to deplete due to long term use of non-sulfurous fertilisers and rapid mineralisation of native soil organic sulfur resulting in sulfur deficiency in soil and hence in the plant. The recent studies conducted on soil application of sulfur as a nutrient reveal the following.

1. Sulfur at 20-45 kg/ha improves yield of tea when soil available sulfur does not exceed 40 ppm.
2. Response in Dooars is not universal due to high soil organic matter and available sulfur.
3. Detrimental effect observed in waterlogged soil due to sulfide formation.
4. Soil sulfur availability increases with increase in organic matter status.
5. High available phosphate has negative effect on sulfur availability.
6. Assam soils have lower available and total sulfur.

Among the different sources of sulfur carriers, elemental sulfur (Sulfex), SOA, Gypsum. Aluminium sulfate were found to be effective.

MICRONUTRIENTS

Among the various micronutrients tried, only zinc has shown consistent response and is recommended to be applied as regular practice in North East India, particularly in unpruned/skiffed teas. However, the deficiency of the nutrient is more physiological than its actual deficiency in the soil and only foliar application of zinc sulphate at 1 to 2 per cent (w/v) is suggested. Addition of urea at equivalent concentration has been observed to improve response. The present recommendation for zinc sulphate application is 12.5 kg/ha for all areas. Foliar application of zinc sulphate at 1 to 2 per cent concentration (not exceeding 12.5 kg/ha) was also found to enhance nitrate reductase activity, nitrogen uptake and protein content in the shoot without any adverse effect on quality of CTC tea.

Foliar application of manganese, boron and molybdenum have shown varied responses and are not recommended as regular practice. Investigations have, however, shown that foliar application of manganese sulphate at 1 to 2 per cent (w/v) substantially increases nitrate reductase activity and protein content in tea shoot. Similarly, boric acid (0.25 per cent) had no adverse effect on theaflavin (TF) and thearubigin (TR) contents of made tea.

FOLIAR NUTRITION

Foliar nutrition is normally considered as complimentary to soil fertilisation for promoting growth. Foliar nutrition is beneficial under stress condition (waterlogging or drought) or coinciding with physiological changes in the bush. NPK 2:1:2, or 2:1:3 where potash status is low, @ 0.5-1 per cent can be sprayed during this period at the following composition.

NPK mixture	**2:1:2**	**2:1:3**
Urea	39 kg	32.8 kg
Di-ammonium phosphate	24 kg	20.4 kg
MOP	37 kg	46.8 kg
	100 kg	100 kg

One kg of the mixture in 100 l water will give 1 per cent concentration. Foliar spraying of potash @ 1 per cent MOP (w/v) during the period of moisture stress can enhance water use efficiency.

SOIL AMENDMENTS

Tea soils exhibit wide variations as regards pH, which ranges from 3 to as high as 5.8. Soils having pH more than 5.5 need to be corrected by application of pyrites/aluminium sulphate.

On the other hand, it is also essential to maintain a soil pH between 4.5 to 5.5 so that increased availability of nutrients is sustained for better nutrition of a tea bush. If the pH is below 4.5, it can be increased by either lime or dolomite application and the rate of liming is given in Table 5.

Table 5. Recommendation on dolomite application.

pH range	Dose of dolomite: Coarse textured soil	Dose of dolomite: Fine textured soil	Mesh size	Time of application	Method of application	Next manuring
Below 4.50	@ 2 t/ha	@ 3 t/ha	80-100	Nov/Dec	Uniform broadcasting & 25 mm deep forking	At least 8 weeks after application following good shower of rain
4.5 - 4.65	@ 1 t/ha	@ 1.5 t/ha	80-100	Nov/Dec		

SOIL MANAGEMENT IN TEA FOR NORTH EAST INDIA

J. Chakravartee and M. P. Sinha

Soil is the medium of plant growth. Of the entire depth of a profile, the top 30 cm of the soil is most valuable agriculturally. It possibly takes hundreds of years for the nature to build a furrow slice (15-20 cm) of the soil, but unplanned use can destroy the same within a couple of years. To ensure optimum growth of plants, the soil has to be maintained in proper physical, chemical and biological conditions.

DETERIORATION OF SOIL

Prolonged cultivation usually brings about deterioration of physical, chemical and biological properties of the soil. Unplanned use can also lead to loss of the fertile top soil by erosion. All these reflect on decline of productive potential of the soil. This can, however, be checked by adopting proper soil management practices. In fact, with the available technology of soil management, it has often become possible to improve productivity of many cultivated soils beyond expectations.

PROPER LAND USE

The major limitations of tea soils in North East India are poor drainage, soil and moisture conservation and maintenance of soil structure. In plains of Brahmaputra Valley it is mostly the drainage while in Cachar, Darjeeling and also in parts of Dooars the soil and moisture conservation requirements coupled with drainage are the major limitations. The Darjeeling hills have been subjected to erosion leading to exposure of parent rocks at some places due to unplanned land use. Proper land use (catchment planning) can help to overcome these limitations.

COMPOSITION OF MINERAL SOILS

The field soil is composed of mineral particles, organic matter, air and water. The volume composition of a mineral soil is shown in Fig. 1.

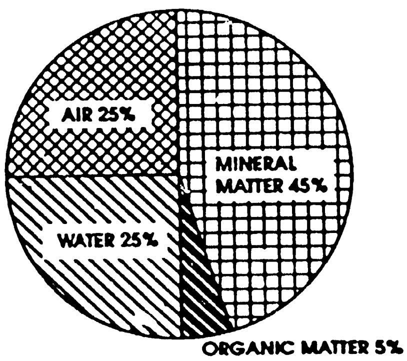


Fig. 1 Volume composition of mineral soils.

TILLAGE/TILTH

Soil tillage is one of the numerous soil management practices adopted for ensuring optimum plant growth. Tilth is the physical condition of soil resulting from tillage operations. Soil is in good tilth when it is friable and adequately aerated. Soils with such

good tilth are supposed to permit rapid infiltration of rain water and to provide conditions optimum for root development. Some of the soil conditions which are effected by tilth and influence plant growth are given below.

Soil Temperature

Tillage regulates plant growth directly and influences physical and biological functions like moisture, aeration, structure, microbial and enzyme activity, decomposition of plant residues and availability of plant nutrients. Microbiological activity in the soil is very much restricted at temperature below 10°C and is optimum at 25°C to 35°C. Soil temperature has a pronounced effect upon the decomposition of organic and mineral components of the soil, resulting in release of plant nutrients as well as in clay formation. The rate of chemical reaction almost doubles with rise of every 10°C in temperature. Soil temperature is increased by tillage primarily by increasing evaporation of soil water.

Soil Moisture

Tillage increases infiltration rate and water storage capacity of a soil. Water affects many physical and chemical reactions of the soil with consequent effect on plant growth. Water is retained in pore spaces of the soil by negative pressure of suction force. It is available maximum to plant around 1/3rd bar suction and very little at 15 bar suction. The soil moisture between these two limits is usually referred to as available water.

Movement of water into soil is called infiltration. Some major factors affecting the infiltration rate are the initial moisture content, condition of soil surface, hydraulic conductivity, texture, porosity, organic matter, vegetative cover and duration of rainfall. The effect of tillage on infiltration usually lasts only until the soil settles back to its former condition of bulk density.

Soil Texture

Soil physical properties are influenced by particles like sand, silt, clay, gravel and coarser fragments. The relative proportion of these soil separates in a soil sample determines the soil's textural class. Cohesion of these individual particles to form aggregates is called soil structure. Spaces between the soil particles are termed as pore spaces (voids). Soil consistence has reference to the relative stability of soil aggregates.

The International Society of Soil Science recognises 5 classes of soil separates based on their size (Table 1).

Table 1. Particle size of different soil separates.

Fraction	Size (mm)
Gravel	> 2.0
Coarse sand	0.2 - 2
Fine sand	0.02 - 0.2
Silt	0.002 - 0.02
Clay	< 0.002

In soil survey work the textural class is estimated in the field by rubbing the soil between thumb and fingers and its 'feel' is noted (Table 2). The texture of a soil is more or less constant and does not change with tillage practices.

Table 2. Soil classification.

Textural term	Alternate term	Textural class	Feel	Sand, silt & clay content
Very heavy	Very fine	Heavy clay	Very stiff, plastic, cannot be crushed between fingers when dry	Sand : <45% Silt : <40% Clay : >40%
Heavy	Fine	Silt clay, sandy clay	Stiff, plastic, without grit, shine when rubbed, cannot be crushed between fingers	Sand : 35-40% Silt : 20-40% Clay : >35%
Moderately heavy	Moderately fine	Silty clay, loam, clay loam, sandy clay loam	Smooth & floury with little grit, very plastic, dry lumps can be crushed with difficulty	Sand : 20-45% Silt : <28% Clay : 20-35%
Medium	Medium	Silt loam	Slightly gritty, smooth and floury	Sand : <50% Silt : 28-50% Clay : 7-27%
Moderatly light	Moderately coarse	Sandy loam	Gritty, cohesive	Sand : 43-50% Silt : <50% Clay : <7%
Light	Coarse	Loamy sand	Gritty, loose, lightly cohesive	Sand : 70-90% Silt : + Clay : 15-30%
Very light	Very coarse	Sand	Gritty, very loose, without cohesion	Sand : >85% Silt : + Clay : <15%

Soil Structure

Soil structure has a pronounced effect on porosity, hydraulic conductivity, infiltration, water holding capacity and erodibility. The aggregates should be able to withstand rainfall impact and temporary submergence. For optimum crop growth, the soil structure should be such that the infiltration capacity is large, percolation capacity is medium, and aeration is sufficient without being excessive. Common methods of soil structure management are proper land use, tillage at suitable moisture content, subsoiling, addition of organic matter, liming, mulching, drainage, irrigation and use of soil conservation practices.

Bulk Density

It is defined as the ratio of mass of soils and its volume :

$$d = M/V$$

wherein, d = Bulk density, g/cc
M = Mass of soils, g
V = Volume of soil sample, cm^3

The bulk density is influenced by the soil structure, texture and compactness. It has considerable influence on the water holding capacity of soil and its hydraulic conductivity. When bulk density exceeds about 1.70 g/cc, the hydraulic conductivity values will be so low that drainage may become difficult. Particle density of most mineral soils usually varies in the range 2.60 to 2.75.

Porosity

Porosity is defined as the ratio of the volume of pores to the total soil volume. It is of great importance, since the chemical and biological processes occur in the pores. Large pores induce aeration and infiltration, medium-sized pores facilitate capillary conductivity and small pores induce greater water holding capacity. Under the conditions of high rainfall the water storage pores (small pores) are not so important, but aeration pores are essential for optimum plant growth.

Two major classes of soil pores are capillary and non-capillary types. Capillary pores are those which remain occupied by capillary water. Non-capillary pores remain filled with air after the soil has drained to field capacity.

Soil Profile

It is a vertical section through the soil mass. Significant changes in texture and structure with increase in depth are observed in most soils. The soil column in most cases is composed of a series of layers that are parallel with the soil surface and are called soil horizons. The "A-horizon" is the zone of maximum biological activity. The "B-horizon" includes the lower layers of soil column and has a blocky or prismatic structure with low organic matter content. The "C-horizon" is a layer of unconsolidated material with very little action of organisms.

SOIL TYPES OF TEA AREAS

Alluvial Soils

Alluvial soils are formed by transportation in streams and rivers and are deposited in plains. These are generally deep soils. These have fairly good water holding capacity and are usually manageable from tillage and water management points of view. These soils are fertile and respond well to manuring. The majority of tea soils of Brahmaputra Valley as well as Cachar are of alluvial origin.

Red Soils

These occur in a few places in Dooars and are sandy loam to loam with pH ranging between 5.0 and 6.0.

Terai Soils

These occur along the foothills of the Himalayan range in West Bengal and are fairly deep and moderately fertile. These soils are deposited as a result of their movement through water erosion of the Himalayan range. The lower strata are, however, formed of water-worn rounded stones and gravels of miscellaneous rocks moved down from the hill ranges. These areas suffer from excessive seepage problem but once drainage is improved, the soils become highly productive.

SOIL pH

The term pH is used to indicate acidity or alkalinity. It is defined as the negative logarithm of hydrogen ion concentration in moles per litre.

At pH 7.0 the concentration of hydrogen and hydroxyl ions are equal and the state is called neutral. The solution is acidic from pH 0 to 7.0 and alkaline from 7.0 to 14.0. Soil pH has significant influence on availability of plant nutrients as well as microbial activity. The relative availability of essential plant nutrients in well drained mineral soils in relation to pH is shown in Fig. 2.

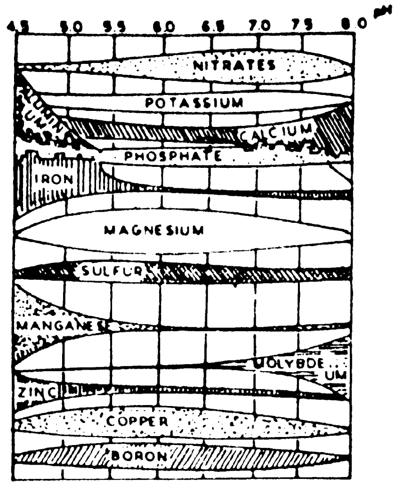


Fig. 2. Nutrient availability as influenced by pH.

EFFECTS OF MULCHING AND ADDITION OF ORGANIC MATTER

1. Mulching reduces the impact of falling raindrops, surface run-off and erosion. As a result, more water can penetrate into the soil.
2. Mulch reduces evaporation losses of soil moisture.
3. Mulch lowers the soil temperature in summer and keeps the soil warmer in winter. As a result, plant roots grow better.
4. Addition of organic matter improves the soil structure. Plant roots are thus in a better position to take up nutrients, water and oxygen more freely.
5. Organic matter serves as food to microorganisms in the soil and thereby improves their activity.
6. Organic matter improves soil fertility status, supplying essential elements in easily available forms.
7. On decomposition, organic matter releases organic acids which help in making slowly available nutrients more available to plants.
8. Organic matter makes soil phosphorus more readily available. Upon decomposition, organic matter releases certain organic compounds which combine with iron and aluminium more readily than does phosphorus. As a result, less insoluble Fe-P and Al-P are formed and more phosphorus is made available.

SOIL REHABILITATION

Physical and biological properties of the soil after remaining under tea for a long time get deteriorated considerably, and some toxic chemicals may also get accumulated. Because of this it becomes very essential to rehabilitate the uprooted tea soil before it is replanted. By doing this the organic matter content also gets improved. Guatemala and mimosa are ideal crops for this purpose. Rehabilitation crops should be manured with 10:5:10 NPK mixtures @ 600 kg/ha, and after each lopping 300 kg/ha. It is strongly recommended that loppings should be left in situ. Rehabilitation period will depend on the build-up of organic carbon in the soil. It is desirable to have carbon status above 1 per cent. For this, rehabilitation period can be 1.5 to 2 years. Rehabilitation is advisable to follow the concept of minimum tillage, and it has the following effects.

1. It adds organic matter and nitrogen to the soil.
2. It helps improving soil structure and thereby better aeration and moisture storage. It also moves nutrients from deep layers to the top layer of soil.
3. Rehabilitation increases the activity of microorganisms.
4. It increases the availability of other plant nutrients and conserves top soil.

A green manuring crop should have the following characteristics :

1. It should yield a large quantity of green material in a short period of time.
2. It should be quick growing to be able to suppress the weeds.
3. It should have more leafy growth than woody growth so that its decomposition will be rapid.
4. It should have a deep and fibrous root system to penetrate deeper into the soil and improve soil structure.

Dry matter content and nutrients added to the soil by some of the more commonly grown green crops are given in Table 3.

Table 3. Rehabilitation crops for tea soils.

Crops	Dry matter added kg/year/ha	Concentration of nutrients (%)		
		N	P_2O_5	K_2O
Guatemala	18,000	1.7	0.70	1.80
Mimosa	14,000	2.6	0.60	1.0
Citronella	8,000			

SOIL TESTING

Soil testing is a valuable tool for assessing the fertility status of a soil and consequently for fertilizer management. To make soil test a valuable diagnostic tool, reliable and representative soil sampling is important.

IMPROVEMENT AND MAINTENANCE OF SOIL FERTILITY

For increased productivity and sustained high yield, it is essential to follow proper soil management techniques which will conserve the valuable top soil, ensure satisfactory root growth, improve soil tilth and maintain soil pH and organic carbon at their optimum desirable levels. Some of the management practices that have been found beneficial for tea are as follows :

Soil Conservation

The following measures may be adopted for conservation of top soil :

1. Minimum tillage practices
2. Controlled weed control
3. Strip weed control
4. On steep slopes planting tea on graded contours
5. Use of suitable soil conditioners
6. Infilling vacancies
7. Proper shade
8. Good mulching
9. Systematic drainage and irrigation (if required)
10. Proper land levelling
11. Aforestation

Soil pH

Tea grows best within a pH range of 4.5 to 5.5. Soil samples should be analysed regularly for assessment of acidity status and necessary corrections can be carried out as per guidelines given below :

Correction of high soil pH : Certain tea gardens get affected by surface and sub-surface seepage flow that come from the adjacent hills having dolomite stones. Lowering of pH in such areas is done through application of iron pyrites or aluminium

sulphate @ 2 t/ha. Application of iron pyrites has gained wide popularity due to its low cost and easy availability. For desired result, the pyrites should be broadcasted evenly over the area. It should be allowed for oxidation for a minimum period of 15 days and then mixed with the soil through forking to a depth of 7 to 15 cm (3" to 6"). A light irrigation after forking will be beneficial.

Repeated application of pyrites may be required based on soil test report every year. In addition to chemical amendments, it will be essential to provide 150 cm deep interceptor drain to cut-off the subsurface seepage flow from the adjacent high area. The effect of various chemicals on soil pH are shown in Table 4.

Table 4. Effect on different chemicals on soil pH.

Treatment dose	S-pyrites	Iron-pyrites	Aluminium sulphate
0 t/ha	7.718	7.718	7.718
2 t/ha	7.083	7.163	6.841
3 t/ha	6.937	7.043	6.591
4 t/ha	6.717	6.944	6.441
CD at 5% = 0.396			
CD at 1% = 0.527			

Though the differences among three chemicals as regards to their effectiveness in lowering pH were non-significant, aluminium sulphate was most effective. Fe-pyrites and S-pyrites were found to be more or less equally effective.

Correction of low pH : To improve low soil pH, application of dolomite is advised. The dose of dolomite will be as per soil test data. The desirable range of pH for tea is 4.5 to 5.5. Dolomite should not be applied if the soil pH is satisfactory.

The requirements of dolomite and pyrites for correction of soil pH are given in Table 5.

Table 5. Correction of soil pH.

pH	Corrective measure
Less than 4.50	Apply 80-100 mesh dolomite @ 2 t/ha in dry winter months and mix it with the soil by forking.
4.51 to 4.65	Apply dolomite @ 1 t/ha in dry winter months and mix it with the soil by forking.
4.66 to 5.60	No chemical amendment is required.
5.61 to 5.80	Apply pyrites @ 2 t/ha, allow 15 days for oxidation then fork into the soil. In addition, provide 150 cm deep interceptor drains at required locations.
More than 6.50	Normally unsuitable for tea plantation.

EFFECTS OF LIMING ON SOIL PROPERTIES

Physical Effects

1. It improves fine textured soils to less sticky and more crumby.

2. It improves soil tilth and porosity. As a result, it provides favourable conditions for root growth and water movement in the soil.

Chemical Effects

1. It makes potassium and phosphorus more available.
2. It supplies calcium and magnesium for plant nutrition.
3. It changes or neutralizes the injurious effect of harmful compounds present in the acid soils.

Biological Effects

1. It hastens the decomposition of organic matter through improved microbial activity.
2. It makes conditions favourable for nitrification.

LIMING MATERIALS

Slaked lime, calcium hydroxide $Ca(OH)_2$	:	Ca = 54%
Quick lime, calcium oxide (CaO)	:	Ca = 71%
Dolomite (calcium carbonate and magnesium carbonate)	:	Ca = 22-24% Mg = 8-20%

Lime requirement of the soil should be determined every 3 to 5 years by soil test. Liming a section that does not need it is a waste of money and may actually reduce crop yield.

Dolomite is generally broadcasted uniformly on the ground and then worked into the soil for optimum efficacy. It should be applied in winter months at least 6-8 weeks prior to manuring. In sandy loam soils application of 1 t of dolomite per hectare increases pH by 0.3 to 0.5 units in one year. In loam and fine textured soils, application of dolomite @ 1 t/ha increases pH by 0.2 to 0.3 units in one year.

ORGANIC MATTER MANAGEMENT

The fertility status of a soil is directly related to its organic matter content, and the comparative ratings are given in Table 6.

Table 6. Rating of fertility status of tea soil.

Organic carbon %	Fertility status
Below 0.60	Very low, unsuitable
0.61 - 0.80	Moderate, marginally satisfactory
Above 0.80	Satisfactory, suitable for tea

The organic matter status of the areas due for planting can be improved through optimum rehabilitation with suitable green crop. The growth of tea will be unsatisfactory and response to applied fertilizers will be poor if the carbon content of soil is less than 1 per cent. Sections that have already been planted with tea and cannot be rehabilitated should be treated with organic matter extraneously. Following measures are beneficial to help in reducing inorganic fertilizer application and improving quality to fetch better price.

1. Application of oil cake as per soil texture @ 2-3 t/ha/year or application of cattle manure @ 3 to 5 t/ha/year.
2. Mulching with suitable grasses to 100 mm thickness.
3. Retain the pruning litter and shade tree droppings in the section.
4. Addition of decomposed tea waste @ 1 to 2 t/ha/year.

The estimated nutritional values of some materials are given in Table 7.

Table 7. Per cent nutrient values* of various organic materials.

Materials	N	P_2O_5	K_2O
Decomposed Cattle manure	0.75	0.25	0.28
Compost manure	0.60	0.45	0.85
Tea waste compost	3.60	0.60	2.30
Deoiled neem cake	1.95	1.20.	3.10
Paddy straw	0.36	0.08	0.71
Tea pruning litter	2.00	0.50	1.50
Shade tree droppings	2.50	0.70	0.80

* data on dry wt. basis

MOISTURE DETERMINATION OF ORGANIC MANURE

Take 50g of fresh organic manure in a container. Keep this overnight in an electrical oven at ≅ 100°C temperature. After 24 hrs. of oven-dry, take the weight immediately without allowing the manure to absorb atmospheric moisture. The difference in the weights of fresh manure and dry manure is the moisture present in the fresh manure. This difference in weights multiplied by "2" is the per cent moisture present in the fresh manure sample.

DRAINAGE

The main objective of drainage is to remove excess water from the root zone area to create a favourable environment for the roots. With poor drainage it is not expected to get desired response from other inputs. Therefore, with the help of a scientifically designed drainage system a favourable air-water balance should be maintained in the root zone area. To achieve this the water table should be controlled below 90 cm from the ground level.

IRRIGATION

The areas that suffer from moisture stress during winter months should be considered for irrigation. It is a well known fact that the fertilizer availability and use efficiency are optimum under irrigated conditions.

BALANCED MANURING

The inorganic fertilizers and organic manures perform different functions and are not competitive but complimentary. A judicious combination of both inorganic fertilizers and organic manures is the key to successful cultivation of tea. Due to changes practices of soil and plant management, the tea gardens are applying at times higher doses of inorganic fertilizers whereas the organic matter status of tea soils has depleted considerably. Due to this imbalance, the response of applied fertilizers is not satisfactory. To maintain desired level of soil fertility, it is important to follow the concept of balanced manuring i.e. a proper combination of NPK fertilizers with suitable organic manures as per soil test report.

MANAGEMENT OF YOUNG TEA

M. P. Sinha, M. K. Banerjee and S. K. Pathak

INTRODUCTION

Sustained higher production is the primary requirement in tea or for that matter in any perennial crop. To fulfil this requirement adoption of a suitable package of agro-practices is necessary. Well managed young tea is an investment for the future.

Young tea management technology has undergone considerable changes over the last several decades. During the formative years more crop is harvested now than ever before resulting in a shorter pay back period and yet assuring long term higher productivity. Comparative study of the yield progression under commercial conditions during 1970-80 and 1980-90 is given in Tables 1 and 2.

Table 1. Yield trend from young tea, kg/ha (excluding Darjeeling).

Period under study	Year after planting				
	1	2	3	4	5
1970-80	260	1083	1664	2067	2289
1980-90	478	1623	2120	2465	2725

Table 2. Yield progression of young tea between +1 and +5 years in various regions of N. E. India (kg/ha).

Region	Year after planting				
	1	2	3	4	5
Upper Assam	504	1775	2248	2962	2820
Mid Assam	250	876	1407	1742	1908
North Bank	579	1742	2209	2413	3217
Cachar	362	1344	2050	2214	2320
Darjeeling	43	266	422	535	642

Various aspects that contribute to bring a happy balance between the two factors i.e. (1) more early crop and (2) the formation of good frame for long term high productivity are discussed.

DENSITY OF POPULATION

Agronomic desirability and economic return play a major role in deciding the optimum stand of tea. Sustained high yield will depend on the formation of good frame and optimum density of sticks over the area. This is possible only when the plant arrangement and spacing are such that there will be enough scope for proper development of each bush without leaving any idle space.

Yield obtained under different plant populations during the first 10 years of plantation in two important agro-climatic regions of Assam Valley indicates broadly the optimum plant population per hectare (Table 3).

Table 3. Cumulative yield (KMTH) of first 10 years obtained from different plant populations

Plant population/ha	Upper Assam	North Bank
12,345	19,655	18,524
14,000+	19,572	NA
15,000+	23,329	20,993
16,000+	22,480	21,483
17,000+	23,897	22,413

NA = Not available

A guideline is given in Table 4, although actual population will be approximately 5 per cent lesser than the calculated one.

Table 4. Spacing and bush population

Spacing	Calculated plants/ha
100 cm X 60 cm	16666
105 cm X 60 cm	15873
105 cm X 65 cm	14652
105 cm X 75 cm X 65 cm•	15686•
105 cm X 75 cm X 70 cm	15238
105 cm X 75 cm X 75 cm	14814
105 cm X 75 cm X 60 cm	16161
105 cm X 70 cm X 65 cm	16806
105 cm X 70 cm X 70 cm	16122
110 cm X 70 cm X 70 cm	15873
110 cm X 75 cm X 60 cm	15686
110 cm X 75 cm X 65 cm	15238
110 cm X 75 cm X 70 cm	14815
110 cm X 70 cm X 60 cm	16806

Double hedge planting has an edge over single hedge for first 7 to 10 years, thereafter the advantage gradually disappears. However, to provide the best environment to each bush, arrangement of plants is most important. It is found that the following spacings only are conducive for sustained productivity :

	For Plains	For Hilly Areas
Minimum spacing between plants	70-75 cm	60-65 cm
Minimum spacing between rows	105 cm	90-100 cm

CHOICE OF PLANTING MATERIAL

Clones and seed stocks best suited to the region should only be chosen. A single clone/jat should not normally exceed 10 per cent of the estate area. Both quality and yield should receive due consideration. For more details, lecture note on "Planting Materials - Judicious Blend for Yield and Quality" may please be referred.

NURSERY PLANTS

Use sleeve size 6" x 9" (15 cm x 22 cm). It will require about one truck load (180 cft) of soil for filling up 2800 sleeves.

Stem thickness	:	0.5 - 0.8 cm
Height	:	40 - 45 cm
Foliage	:	12 - 16 leaves/plant

Sleeve soil should remain intact with undamaged root system in it at the time of transplanting; if required, cut overgrown roots at the bottom of the sleeves with a knife.

PLANTING

Pit Size

45 cm x 45/60 cm

Planting Mixture Per Pit

Well rotten dry cattle manure	:	4-5 kg
Super phosphate	:	30 grams
Rock phosphate	:	30 grams

Place rock phosphate at the bottom of the 'bheti' and super phosphate about 5 cm below the ground level after mixing with the excavated soil. Granular, systemic insecticide like Phorate (@ 2.5 g/plant) and E.C. formulations like Chlorpyriphos/Endosulfan are generally used at the time of planting to offer protection against soil borne insects. When granular insecticide is used it should be mixed with a portion of excavated soil and applied to the upper half of the pit. When Chlorpyriphos or Endosulfan formulations are used, the spray fluid can be applied at the collar of plants after planting.

Planting Out in Field

While planting seedlings the top of the sleeve/bheti should remain flush with the ground level. In case of clonal plants the tip of the cuttings should remain slightly above the ground. Proper ramming and ground levelling are very important.

BUSH FRAME

The frame is formed in three stages viz. (a) decentering, lung prune, or debudding, (b) formative prune 20-26 months from planting and (c) frame formation.

The objectives of (a) and (b) are to suppress central dominance and apical growth, distribute vigour for even radial spread so that in stage (c) there is uniformity in distribution and thickness of branches at pruning level.

The permanent frame is formed at a height which will ensure optimum coverage of the ground. The height of the permanent frame will be influenced by spacing and the jat of tea and should normally be at 35-45 cm from the ground. Normally, there will be no need to prune the teas below this height during its economic life.

There are three basic methods by which the apical dominance of the main stem of a tea plant can be diverted to develop spreading lateral branches. These are (a) decentering, (b) lung pruning or thumb pruning and (c) debudding.

Decentering

The main stem is removed by a 3" (7.5 cm) pruning knife at a height of about 20 cm from the ground. This operation should be done after the plants make one flush of growth following transplanting in the field and when they are at banjhi stage. Root starch is considered important for recovery after decentering.

Lung Pruning or Thumb Pruning

The seedling is held between the thumb and the index finger at about 20 cm and the stem is half broken in such a way that the tissues on one side are left intact for movement of water and nutrients. The broken portion should be bent towards the ground facing either South or West depending on row direction. The broken portion should be removed after the branches below it produce a flush of growth and go banjhi. Lung pruning can also be done by using a small pruning knife.

Thumb pruning appears to be the safest method to suppress the central dominance and to distribute the initial vigour.

After 6-8 weeks of decentering or lung/thumb pruning any leader primary should be head backed depending on thickness to 25-30 cm from the ground.

Debudding

Buds from the leaf axils are removed upto the normal level of 20 cm from the ground. Two weeks before debudding the top two and a bud should be nipped off from plants in the nursery. This will help to swell the buds below. Four to five days before the plants are taken out to the field they can be debudded in the nursery. Debudding in the nursery is more thorough, convenient and economical.

Frame Forming Prune

The frame forming prune should be given at a height 5-10 cm below the pre-determined height of the permanent frame. Thicker branches should be pruned down on merit (head back) and any congestion at the centre removed.

Besides distributing the bush vigour to the peripheral branches, this prune results in the ramification of branches of even thickness on the permanent frame.

Permanent Frame

Bush architecture : An ideal bush frame is one which will have a three-tier branching system in the proportion of 1:3:7 at decentering/debudding, frame forming prune and permanent frame forming levels respectively. Each tier of branches should have adequate thickness and number to support the one above it.

Number and thickness of branches : On an average there should be 26 to 32 branches on the permanent frame. Seventy per cent of these branches should have a thickness of 0.5 - 1.0 cm. Judicious pruning at the time of giving formative prune is important to achieve this objective.

Frame size and density of branches : The bush frame should have a spread of 2700 sq. cm - 3200 sq. cm (e.g. 60cm x 45cm, 65cm x 45cm, 65cm x 50cm etc.). It should have a density of one stick per 100 sq. cm of frame area. The permanent frame should cover 36-40 per cent of the ground area.

METHODS OF BRINGING UP

Keeping in mind all the factors discussed in the preceding text, the best method(s) of bringing up may be as follows :

A. For non-droughty areas

YEAR	MONTH	OPERATION	PLUCKING
0	October - December	Plant tea	Allow to grow
+1	Early February - mid April (soon after establishment)	Thumb prune or decentre at 20 cm	Tip at 60-65 cm ground measur
	June - July (i.e. at tipping time)	Selectively remove strong central and/or criss-cross branches	
	End October	Step up by a leaf, if necessary	
+2	-	Unprune	Pluck to Janam
+3	Between end January and early February	First frame forming prune at 35-40 cm. Remove/head back thick central branch(es), if necessary	Tip at 60-65 cm
	End October	Step up by a leaf, if necessary	
+4	-	Unprune	Pluck to janam
+5	Between end January and early February	Final frame forming prune at 40-45 cm. Remove/head back thick central branch(es), if necessary	Tip at 65-70 cm

Note : Higher measure is beneficial in single hedge/widely spaced double hedge and in slopy areas to achieve quick ground coverage and have thick primaries. In this way, subject to thickening of primaries to ideal size, the tea bushes may receive the first frame forming prune even at the end of +1 year.

B. For droughty areas

YEAR	MONTH	OPERATION	PLUCKING
0	April - June	Plant tea	Allow to grow
	July - August (soon after establishment). Incase of late planted/ weak teas defer to next early February - mid April	Thumb prune, decentre or debud at 20 cm. Selectively remove strong branches and/or criss-cross branches at the time of tipping	Tip at 60-65 cm ground measure
+1	-	Unprune	Pluck to janam
+2	Between end January and early February	First frame forming prune at 35-40 cm. Remove/head back thick central branch(es), if necessary	Tip at 60-65 cm
	End October	Step up by a leaf, if necessary	
+3	-	Unprune	Pluck to janam
+4	Between end January and early February	Final frame forming prune at 40-45 cm. Remove/head back thick central branch(es), if necessary	Tip at 65-70 cm

Note : In severe droughty areas instead of leaving the tea unpruned in +1 year, first frame forming prune at 35-40 cm is suggested.

C. For hilly areas : Low elevation

YEAR	MONTH	OPERATION	PLUCKING
0	Jun-Jul	Plant tea	Allow to grow
+1	Jan-Feb	Decentre/thumb prune or debud at 15-20 cm. Selectively remove strong central branches and/or criss-cross branches at the time of tipping	Tip at 55-60 cm
+2	-	Unprune	Pluck to janam
+3	Jan-Feb	Formative prune at a height of 30-35 cm. Remove congestion selectively	Tip at 55-60 cm and pluck to janam
	Jul-Aug	Step up by a leaf, if necessary.	
+4	-	Unprune	Pluck to janam
+5	Jan	Final frame forming prune at 35-40 cm. Remove congestion selectively	Tip at 60-65 cm

D. For hilly areas : Medium/high elevation

YEAR	MONTH	OPERATION	PLUCKING
0	Jun/Jul	Plant tea	Allow to grow
+1	Jan-Apr	Debud/decenter/thumb prune at 15-20 cm. Selective removal/head back dominant branches	Tip at 50-55 cm and pluck to janam
	Early Sep	Step up by a leaf, if necessary	
+2	-	Unprune	Pluck to janam
+3	Jan/Feb	Formative prune at 30-35 cm. Remove congestion selectively	Tip at 50-55 cm and pluck to janam
	Early Sep	Sep Step up by a leaf, if necessary	Pluck to janam
+4	Early Sep	Unprune, step up by a leaf, if necessary	Pluck to janam
+5	-	Unprune	Pluck to janam
+6	-	Final frame forming prune at 35-40cm. Remove congestion	Tip at 55-60 cm and pluck to janam

Thereafter follow pruning cycle as for the mature tea.

SOME IMPORTANT CULTURAL PRACTICES

Land Planning

Topographical planning for laying out drains and bunds, culverts and plucking access will greatly help in soil-water disposal and conservation, easier supervision, cheaper maintenance and better utilisation of mandays in plucking, spraying, cultivation, etc.

Mulching

The benefits of mulching are many. It conserves soil water, adds organic matter and nutrients, improves soil tilth, keeps the soil warmer in winter and promotes growth of soil microflora essential for plant growth. Availability of mulching is sometimes a problem in many estates. Under such situation a thin layer of mulch may first be spread on the ground to quickly cover it after planting. It should later be topped up. Mulching for moisture conservation must be completed by middle of November. Generally 10 cm thick mulch requires approximately 15 tonnes of Guatemala loppings per hectare.

Though water hyacinth and Guatemala grass are the best mulching materials, any vegetative material such as citronella, thatch and paddy straw can also be used as second rate materials. For decomposition of the later group of grasses apply 100 kg of ammonium sulphate per hectare evenly spread on top of the mulch. The mulch should be kept about 10 cm away from the collar of the plant to avoid heat and cockchafer damage.

Weed Control

Pre-emergent :

Simazine @ 1.00 kg/200 litres water.
Oxyfluorfen (Goal) @ 0.5 l/200 litres water.

Post-emergent :

Glyphosate against thatch and other grasses @ 1:200.

2,4-D and Paraquat to be used with care @ 1:400.

Shade

Temporary : *Indigofera teysmanii*, *Leucaena lucocephala*, *Albizzia chinensis* and *Melia azedarach* (Ghora neem).

Permanent : *Albizzia odoratissima*, *A. lebbek*, *A. chinensis*, *Dalbergia sericea*, *Acacia lenticularis*, *Derris robusta* and *Adenanthera pavonina*.

Pest and Disease

It is of utmost importance to keep young tea free from any pest or disease attack. The common pests are thrips, greenfly and mites. Caterpillar pests like Looper, Red slug and Bunch are periodic and localised. While cricket can be a nuisance during the early period of establishment in some areas, cockchafer poses a great problem upto 4-5 years from planting. Treatment against termites is particularly important in replanted areas.

Red rust is the most common disease which is normally carried by the plants from the nursery when kept there for longer duration or when the plants become weak due to any limiting factor. The young shade plants should also be treated with the same chemicals when applied to tea. Leaf-eating caterpillars on shade plants are conspicuous during April-May and July-September. They should be treated with as much attention as the young teas.

NUTRITION

During formative stage the young teas should be fertilized with NPK 2:1:2 or 2:1:3 mixture at rates given in Table 5.

Table 5. Young tea manuring during formative stage.

Year of planting	Nitrogen kg/ha	YTD manure kg/ha	No. of splits	Method of application
0 Year	20-40	200 - 400	2-3	Ring (depending on time of application)
+1 Year	80-100	800 - 1000	4	Ring
+2 Year	100-120	1000 - 1200	4	Ring
+3 Year	120-140	1200 - 1400	4	Ring
+4 Year	140-150	1400 - 1500	2	Strip application
+5 Year	140-150	1400 - 1500	2	Strip application

A 2:1:3 NPK mixture should be adopted where the soil potash level is below 100 ppm.

Foliar Spraying

Zinc sulphate and magnesium sulphate along with urea and MOP depending on season, jat and growth of young tea are found to be useful.

SHADE - IMPORTANCE AND SILVICULTURE

I. D. Singh and B. Borthakur

IMPORTANCE

Importance of shade in tea was realised long ago and its organised planting in tea plantations of North East India had started towards the end of the last century. The "Sau" tree (*Albizzia chinensis*) was the first shade species used for planting and later other species were included. In Tocklai, extensive investigations were carried out since the late forties to understand various aspects related to leaf temperature, effect on photosynthesis, addition of nutrients, etc. The salient information generated from these investigations is summarised below :

1. Deep rooted shade trees help in conserving soil moisture particularly during the moisture stress period. Shallow rooted species like *A. procera* may compete for soil moisture in drought prone areas like Terai and the Dooars.

2. Shade trees (*A. chinensis*) add 2500-5000 kg/ha organic matter to the soil annually by dropping leaves, twigs and pods. The estimated nutrient contents of this added organic matter are :

N	=	63 - 126 kg
P_2O_5	=	18 - 36 kg
K_2O	=	22 - 44 kg
CaO	=	32 - 64 kg
MgO	=	16 - 32 kg

3. Under *A. chinensis* shade trees, feeder roots of tea develop at a higher rate than without shade.

4. April to October is the major growing season in North East India. Leaf temperature during this period varies between 30 to 45°C depending upon the presence of wind at ambient temperature of 30 to 32°C.

5. The leaf temperature of shaded leaf remains 1 to 2°C higher than the ambient temperature, whereas under unshaded condition the same may be 2 to 12°C higher than the ambient temperature.

6. Photosynthetic activity in tea declines rapidly above 35°C leaf temperature and between 39 to 42°C there is no net photosynthesis. The respiration continues upto 48°C and leaf temperature above 48°C damages leaf tissues.

7. Shade trees absorb a large amount of harmful infra-red radiation from the solar spectrum (over 70 per cent of the total present in full sunlight).

8. There is a fall of temperature by 0.6 - 0.7°C for every rise of 100 metres in elevation upto 900 metres. Above this elevation, the fall in temperature is rapid. Therefore, above 900 m elevation in tea plantations shade trees may not be necessary.

9. Positive effect of shade cannot be replaced by additional application of nutrients.

10. Shading diverts relatively large portion of the assimilates towards pluckable shoots and thereby increases yield.

11. A shade species with single layer of canopy composed of small leaflets, which will allow sunlight in the form of sunflecks and will cut off about 50 per cent of the total available sunlight, is considered best. *Albizzia chinensis* meets these requirements to the best.

SILVICULTURE

Seed

Selection of mother (plus) trees : As a source of reliable seed, it is better to select moth. trees of the required species having desired characteristics and marked properly in advance.

Collection : The seeds are usually borne in pods and the pods should be collected as soon as they turn brownish while they are still on the trees during the cold weather. Do not collect seeds from the ground.

Extraction and storage : The pods should be thoroughly dried in sun for a few days and the seeds should be extracted by lightly pounding the dried pods. Following winnowing, the clean seeds should be stored in wooden bins/gunny sacks in well ventilated cool and dry room. Seeds are easily attacked by pests and, therefore, should be treated with 5 per cent Malathion dust @ 100 g/kg of seeds prior to storing.

Nursery

1. Lay out nursery nearer to a perennial source of water.
2. Shade tree seedlings grow best in well drained sandy loam soils.
3. When rich virgin soil is not available, improve the soil condition by the following treatments.

   Well rotten cattle manure @ 25 t/ha

   Slaked lime or dolomite @ 2 t/ha

   In order to add wood ash, heap up dry jungle litter and burn. The ash thus obtained should be mixed up with the bed soil.

4. November to December is the ideal time for soil preparation. Deep ploughing, harrowing and levelling will be required. A good tilth of soil must be worked out. The individual bed should be loosened to a depth of 60-70 cm.

   After the beds have been prepared, application of single superphosphate @ 125 g/sq m of bed area is recommended as broadcast.

5. Drainage of the nursery must be efficient and drains should be provided as given below :

Between beds	:	Depth	- 60 cm
		Width	- 45 cm
Periphery	:	Depth	- 120 - 150 cm
		Width	- 60 cm
6. Size of beds		Width	- 150 cm
		Length	- As per convenience
7. Polythene sleeves	:	Size	- 30 cm lay flat
		Length	- 60 cm
		Thickness	- 300 gauge

Rich light textured virgin soil is preferred for filling sleeves. In absence of virgin soil, prepare the soil mixture as follows :

Friable soil	:	4 parts
Dry well rotten cattle manure	:	1 part
Single superphosphate	:	1 kg per cubic metre of soil
Slaked lime or dolomite	:	0.5 kg per cubic meter of soil

Sowing of seeds

Pretreatment : In order to make the embryo active, soak the seeds in water overnight followed by drying before sowing. Seeds with very hard seed coat can be treated with either hot water (80°C) or conc. sulphuric acid. When treated with hot water, seeds should be immersed in water heated upto 80°C and allowed to cool overnight. When sulphuric acid is used, soak the seeds for 1-2 minutes in conc. sulphuric acid followed by thorough washing in running water.

Time of sowing : February - April

Method of sowing : Depth of sowing = 0.5 - 1.0 cm
Spacing = 20 cm
Interline spacing = 30 cm

Cover up the seeds after sowing with a thin layer of soil and water the beds copiously.

Sowing in polythene sleeves : Drill 2-3 seeds at a depth of 0.5 - 1.0 cm. Cover the seeds with a thin layer of soil and water the sleeves.

Maintenance of Nurseries

Pests : Soak the beds with Endosulfan (1:400) with a hand operated sprayer after sowing of seeds.

It is also necessary to watch the nurseries for prevalence of any leaf damaging insects like psyllids, leaf eating beetles and green caterpillars. As soon as such pests are seen, the nurseries should be sprayed with Endosulfan/ Quinalphos or Monocrotophos (1:400 with hand sprayer).

Diseases : Attack of red rust may cause extensive damage to the seedlings. The disease may occur after a few months of germination. Spraying with copper oxychloride (1:400) at fortnightly intervals during the growing season (April to July) is necessary to prevent the disease. While spraying, drench the foliage and stems to provide protection from both leaf eating insects and red rust. The insecticides mentioned above can be mixed with copper fungicide.

Weeds : Carry out hand weeding regularly to maintain the nurseries free from weed infestation.

Drainage : Water should not be allowed to accumulate in the drains.

Thinning : Thin out the plants to maintain the recommended spacing. While thinning take out the weak seedlings.

Irrigation : Irrigate the beds/sleeves as and when required.

Fencing : The nursery complex should be well protected.

Transplanting

Bheti planting : For planting in mature tea area, the plants should be 1.8 m - 2.1 m tall and the diameter of the stem should be 2 cm.

For planting in young tea area 60-90 cm tall plants will be adequate. The tender top apical shoots of the plants should be cut back to brown wood prior to transplanting while in the nursery and the cut covered with a lump of raw cowdung.

The shade plants should be lifted with a "bheti" 60 cm long and 30 cm in diameter. The plants are to be planted in already prepared pits. Roots found outside the bheti should be cut off. In sleeve-raised plants also the roots at the bottom of the sleeves should be cut off.

Carrot planting : Where lifting the plants with bhetis is not possible for one reason or other, then good results can be obtained by carrot planting. In this method all the soil is shaken off from the roots and the tap root is cut clean with a sharp knife at a depth of about 60 cm but as many of the laterals are retained as possible.

Spacing : The suitable spacing for permanent trees was found to be 10.86 to 12.69 m. Initially closer spacing of 5 to 6 m can be followed for temporary species to be planted in between permanent rows.

Planting pits : The ideal size of planting pit is 90 cm deep and 60 cm wide. In heavy soil, the bottom soil of the pit should be loosened to a further depth of 15 cm. Following is the composition of manure mixture to be used in planting pits.

Dry well rotten cattle manure	:	10 - 15 kg
Single superphosphate	:	0.5 kg
Wood ash	:	0.5 kg
Slaked lime/dolomite	:	1.0 kg

Time of transplanting : In order to get best results the stumps should be planted out as soon as the swelling of axillary buds on the stem takes place. This occurs usually during mid February to end of April. There must be adequate moisture in the soil at the time of planting. In droughty areas,therefore, planting should be delayed.

Vegetative propagation

Certain shade trees can also be propagated vegetatively by the following methods.

Stem cuttings : *Indigofera teysmanii* could be propagated successfully by stem cuttings. However, *A. chinensis* and *A. odoratissima* could not be propagated successfully by this method.

Layering : This is a suitable method for propagating *I. teysmanii*. In this method 2-4 cm long piece of bark is removed from a branch of 3-5 cm thickness and the exposed wood is covered with soil. The soil is held by a strip of gunny bag or polythene fixed firmly with the branch. It is important that the soil is kept moist at all times. Rooting takes place in 2-3 months. April-August is the best time for layering. The rooted stem is cut out and planted.

Root cuttings : Roots of pencil thickness are made into pieces of 20-30 cm length and planted at 45° angle in the callusing beds. While planting keep about 1/3rd of the cutting above the bed level. Polarity must be maintained. Light overhead shade should be given. This method has been found suitable for the following shade species :

Albizzia lebbek
Dalbergia sericea
Derris robusta

Maintenance of Shade Trees

Pests and diseases : Psyllids and leaf eating caterpillars may cause severe damage to the young shade plants. Also the plants are likely to be crippled or killed by red rust disease. These pests and diseases must be controlled timely for successful raising of the shade trees.

Biotic damage : Prevent damage by cattle and goats by providing bamboo/wire guards.

In elephant infested areas *Acacia lenticularis* is preferred. *Melia azedarach* and *Indigofera teysmanii* are also said to be not palatable to elephants.

Drainage : Good drainage must be maintained for successful raising of shade trees.

Lopping : Lower branches of the shade plants should be removed as and when they lose their usefulness due to loss of canopy and wherever the shade is thick. When the permanent shade trees have attained a height of 12-15 ft, the main central stem(s) should be cut back to 8 to 10 ft height above ground to encourage the development of lateral branches.

Shade Tree Species

Choice of species : As far as practicable indigenous species should be selected.

Permanent shade species : Some permanent shade species alongwith their time of flowering and leafless periods are mentioned below :

Permanent shade species	Time of flowering	Leafless period
Albizzia odoratissima	May-Jun	End Dec-End Feb
Albizzia lebbek	Apr-May	Jan-Apr
Acacia lenticularis	May-Jul	Dec-Mar
Dalbergia sericea	Apr-Jun	Dec-Mar
Derris robusta	Apr-May	Mid Dec-Feb
Adenanthera pavonina	Apr-Jun	Jan-Mar

Temporary shade species : The widely used temporary shade species is *Indigofera teysmanii*. It is quick growing and has economic life of 8-10 years. *Indigofera* plants require frequent lopping. Ghora neem (*Melia azedarach*). commonly known as "Bokain". has also been found doing well as temporary shade in N.E. India. Other suitable species that can be used as temporary/semi permanent shade are *Albizzia chinensis*, *Albizzia procera*. *Albizzia falcata*. *Leucaena lucocephala*. etc. These are very fast growing and, therefore, can be profitably used in between the permanent rows.

Shade mixture : An ideal shade species should have a single layer canopy allowing small sunflecks to reach the bush surface. But all recommended species do not have exactly similar pattern of canopy. Besides, their leafless period is also not similar. Therefore, depending on the climatic conditions of a region, ideal shade mixtures are to be selected taking into consideration their growth habit. leafless period and pattern of leaf-canopy.

Monoculture should be avoided as this may lead to large scale destruction in the event of severe incidence of pests or diseases. It is also advisable to plant shade in intimate mixture. The ideal planting pattern of a mixture of four permanent species alongwith temporary species is shown below :

```
A X B X C X D
X X X X X X X      A,B,C,D are four different
C X D X A X B      species of permanent shade. X
X X X X X X X      indicates the place for
A X B X C X D      temporary species.
X X X X X X X
C X D X A X B
```

Shorter rotation : While felling of big trees or during a storm considerable damage is often done to the tea bushes underneath. Incidence of pests and diseases also keeps on increasing in old shade and it is difficult to undertake spraying operation on tall trees. It is, therefore, advisable to replace the shade trees in shorter rotation of 10-20 years. This concept, if adopted, will help in the following.

1. Eliminating problems of pests control.

2. Providing scope to try out new and suitable species of shade with various advantages.

3. Producing firewood in large quantity.

In the event of accepting a policy of shade planting on shorter rotation as discussed above, many of the fast growing species with thin shade canopy can find place in shade mixtures. Under this concept, some possible shade mixtures that can be tried are given below :

Mixture I	:	*Albizzia chinensis, Indigofera teysmanii, Albizzia procera*
Mixture II	:	*Albizzia chinensis, Albizzia procera, Leucaena lucocephala*
Mixture III	:	*Albizzia chinensis, Melia azedarach, Indigofera teysmanii*

A FEW ASPECTS OF PRUNING

J. Chakravartee and A. C. Barbora

Tea is cultivated for succulent vegetative shoots and the plant as such needs to be maintained in vegetative phase of growth all through. As the age from pruning increases, shoot size and weight decrease, increasing number of banjhi shoots appear at the plucking table and more and more buds fail to grow. Under continued plucking, without pruning or skiffing, the growing apices gradually lose vigour. At this stage, pruning becomes necessary to remove numerous small twigs and/or small shoots and thus regenerate a new set of branches (i.e. top hamper) which can sustain vigorous flushing activity in the bush. Occasionally drastic pruning may also be necessary for the elimination of disease and pest ridden branches. Removal of moribund frame and reduction of the load of unproductive wood help restoration of production capacity of the bush.

OBJECTIVES OF PRUNING

Pruning is a natural sequence to plucking and necessary in diverting energy towards production of leaf. The main objectives are :

1. To check reproductive growth and provide stimulus for vegetative growth, specially for production of young shoots that constitute the crop.

2. To remove dead or unproductive wood and renew the actively growing branches which can support sufficient volume of maintenance foliage on it.

3. To control height for facilitating plucking operation.

PRUNING POLICY - AN IMPORTANT CONSIDERATION

The need to maximize productivity has made the field work in tea estates more intensive in character. Pruning with direct bearing on bush productivity is one of the most critical field operations.

The policy of pruning in an estate must ensure the following.

1. Keeping the bushes in such a condition so that maximum number of healthy shoots appear from the pruning sticks and majority of them reach the tipping height in time.

2. Keeping the bushes efficient all the time in respect of health and uptake of nutrients.

3. Harvesting even crop as much as will be possible and maintaining acceptable quality throughout the season.

4. Reduced incidence of pests and diseases.

5. Keeping the bush height within reasonable limits for efficient plucking.

BUSH SANITATION, PREVENTION OF KNOTS AND CLEANING OUT

An allowance of lesser than 4-5 cm of new wood left at the time of pruning stimulates janam axil buds also to grow into primaries. As a result of inadequate allowance left after each pruning the wood at the pruned level fuses into a lump or a compound knot (Fig. 1).

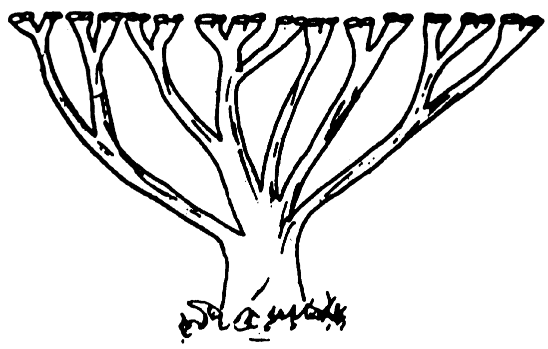


Fig. 1. Wood fuses to form compound knot.

When tipping is done at lesser than the average height of five leaves, the axil bud of the fish leaf often grows to a shoot (Fig. 2).

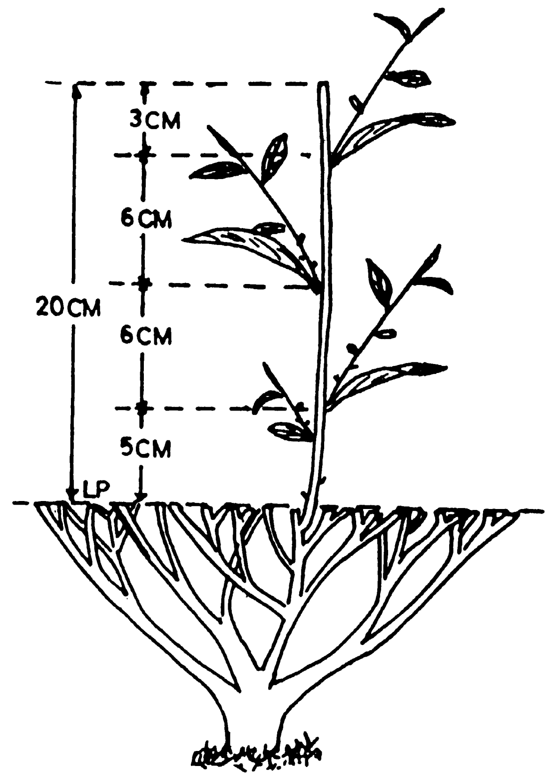


Fig. 2. Low tipping.

The subsequent light pruning will, therefore, be on the forks, instead of a cut on clean primary. Similarly deep skiffing at a level below the third leaf from the top may also force laterals from the axils of the fish leaf and janam of the primary causing formation of knots in the later years (Fig. 3).

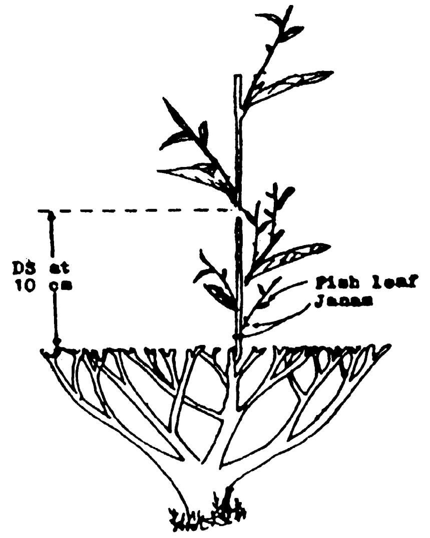


Fig. 3. Deep skiff after low tipping.

Therefore,

1. Tipping in the light pruned bushes should be at a measure corresponding to the average height of five leaves (Fig. 4).
2. If due to knotty bush frame and/or other reasons the primaries go banjhi below 20 cm, the following measures will be necessary :
   a) Tip low but give corrective prune at the earliest opportunity.
   b) Wait till the primaries reach 20 cm and follow a 2/3 year pruning cycle after which prune to rectify the frame.
   c) Selective or partial removal of knots in CA year.
3. Do not prune at a low measure. Minimum allowance of 4-5 cm is necessary.

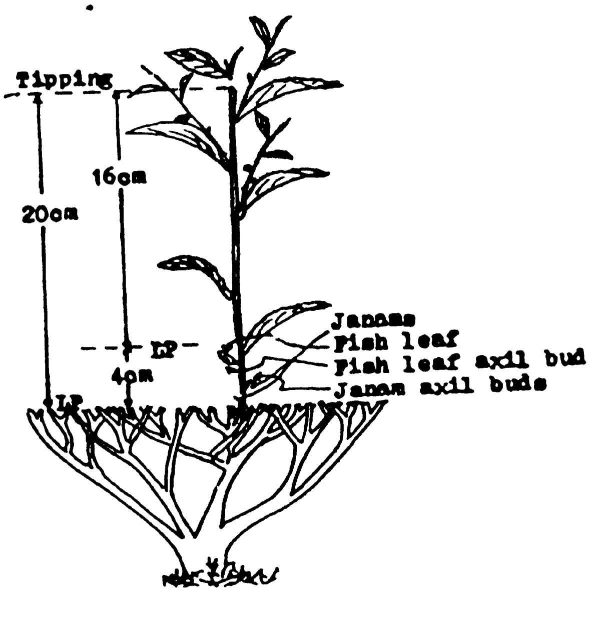


Fig. 4. First dormancy horizon on bushes of average vigour.

Corrective pruning below the general level of the knots is beneficial when there is excessive knot formation. This results in the loss of crop in the pruned year, but there is a steady increase in productivity afterwards.

The general trend of yield progression after corrective pruning (medium prune) is given in Table 1.

Table 1. Yield progression (KMTH) after corrective pruning.

Pre-pruning 1 yr	Year of corrective pruning	After corrective pruning			
		1st yr	2nd yr	3rd yr	4th yr
2219	944	2107	2018	2155	2484

Cleaning Out

Presence of banjhi shoots on a pruned bush retards the growth of new shoots resulting in the loss of crop. Both from bush sanitation and quantity point of view, presence of banjhi shoots on pruned bush was found to be harmful.

An experiment in Tocklai conducted during 1935-49 on the effect of cleaning out at different intervals following pruning showed that too much delay in cleaning out was deleterious and affected the crop adversely. Cleaning out should be done soon after pruning and under no circumstances it should be delayed beyond natural bud break time, which depends on weather and vigour of plants.

Some of the important findings from our experiments conducted during 1936 to 1947 were as follows :

1. Spacing and stick pruning (one shoot only was left on each main branch) reduced crop. This means too much of cleaning out that normally results in removal of live and productive wood is detrimental.

2. If weak and crossing branches are not cleaned out, there is a tendency that they congest the centre of the bush and decrease the yield.

3. Removal of banjhis had significantly increased yield.

4. Removal of dead wood is important but its frequency will depend on the kinds of tea, standard of pruning and general upkeep of the bushes. Dead wood is removed to encourage callusing and to eliminate infection by pathogenic organisms. Removal of dead wood can have no effect on yield if disease enters through the wood.

Defoliation

In a survey experiment in 1963 the effect of long term defoliation in Dooars showed that continuous defoliation of mature tea bushes, as a control measure against red spider, resulted in loss of crop by about 5 per cent in the fourth year and about 7 per cent in the 5th year of defoliation. In this experiment a pruning cycle LP-DS-MS was followed.

TIME OF PRUNING/SKIFFING

Time of pruning not only affects the total yield but also influences the distribution of crop. In general, the optimum time of the year to prune/skiff is when the plant is dormant or its growth rate is the slowest and carbohydrate reserves are high. The exact time depends on the locality, climate, crop and quality requirements, seasonal crop distribution, susceptibility to pest and disease, etc. It was observed that in annually pruned tea the highest total crop was obtained by pruning in December and January. Studies on the movement of photosynthates also revealed that from October the carbohydrates started moving downwards until mid February after which upward movement started again.

Considering the starch reserve in roots, December-January is the ideal period for pruning tea bushes in N. E. India. Though the root starch content was found to be maximum in February, light pruning during this month invariably produces less early season crop compared to December-January pruning.

Results of a few regional trials carried out in mid seventies on times of pruning and skiffing (LP-DS-MS) have proved that, in general, mid December to mid January was the best time for pruning/ deep skiffing in longer cycles also. When pruning was

delayed beyond mid January, there was crop loss in the orders of 17 per cent for North Bank, 3-6 per cent for Upper Assam, 7-8 per cent for South Bank, 10-11 per cent for Cachar and 3-6 per cent for Dooars, depending on the weather conditions. The crop distribution pattern under different agro-climatic conditions of North East India as influenced by times of pruning and skiffing is shown in Table 2.

Table 2. Per cent crop distribution pattern under different agroclimatic conditions of North East India.

Type of tea	Early crop			Mid crop			Back end crop		
Pruned tea									
	A	D	C	A	D	C	A	D	C
Mid October	44	35	34	56	62	66	-	3	-
Mid November	26	26	29	65	61	61	9	13	10
Mid December	18	25	25	62	56	58	20	19	17
Mid January	15	25	24	61	55	58	24	20	18
Early February	12	24	23	64	54	58	24	22	19
Mid February	10	23	22	64	54	58	26	23	20
DS tea									
Mid October	42	34	36	58	64	63	-	2	1
Mid November	33	27	31	61	61	59	6	12	10
Mid December	25	27	27	59	58	57	16	15	16
Mid January	24	24	25	57	58	58	19	18	17
Early February	21	23	24	60	58	58	19	19	18
Mid February	20	22	22	60	59	60	20	19	18
MS tea									
Mid October	46	33	35	54	66	64	-	2	1
Mid November	35	25	30	57	63	59	8	12	11
Mid December	28	25	27	53	57	56	19	18	17
Mid January	24	21	26	53	58	55	22	21	19
Early February	23	23	24	54	57	56	23	20	20
Mid February	22	21	23	54	57	57	23	22	19

A = ASSAM, D = DOOARS, C = CACHAR

In Darjeeling hills, however, pruning/skiffing time can be advanced by about two weeks as the plucking season closes earlier.

Pruning and Moisture Stress

Water is absorbed by the roots and sent up through the stems to the leaves from where it is transpired through the minute pores or stomata on the underside of the leaves. This process continues till the plant can extract water from the soil.

As the depletion of soil moisture proceeds during drought, it becomes more and more difficult for the roots to extract water and this is called "moisture stress".

As the "stress" continues, stomata on the leaves gradually close and prevent moisture loss, but stomatal closure also interferes with the process of photosynthesis and carbohydrate is no longer produced. This, however, does not reduce the consumption of food by the plant and, therefore, during a continued drought the reserves in the stems and roots begin to be used up.

After a long period of drought the leaves become burnt, or dry up and fall off.

There is always a bud on the stem at the point where the leaves are attached. These axillary buds remain in a dormant condition till the plant can remain alive, and it does not lose much water. It continues to use up its food very slowly.

With the onset of rains and as soon as the soil is moistened adequately, the roots become activated again. If all the carbohydrate reserves in the stems and roots have not been already depleted, buds begin to grow.

After the bush has suffered during the moisture stress and if it is then pruned, buds and stems are lost and as a result some reserves on the stems are also lost. This creates three problems to the bush :

1. Greater die-back of the new wood.
2. New buds are to be formed afresh on older wood down below inside the bark. The older the wood the more difficult it is for the buds to grow out and the process becomes slow.
3. New buds have to depend only on root reserves to start with.

PRUNING CYCLE

Pruning cycle consists of a prune followed by lighter forms of cut or unprune until the bushes are pruned again. Substitution of annual pruning by longer pruning cycles through the introduction of skiff and/or unprune, in general, increases productivity of tea. The duration of pruning should be such that the branches will remain uniformly thick leading to a maximum number of pruning sticks on the frame. Majority of pruning, which would have survived in a shorter cycle get generally smothered in a longer cycle. This phenomenon is more pronounced in light leaf Assam jats compared to hybrid Chinary jats, which implies that some clones do not respond favourably to longer pruning cycles.

Choice of Pruning Cycle

A pruning cycle of fixed duration for all sections is not conducive to crop optimisation. Recent study indicates that sustainability is lost after 2-3 repeats irrespective of 3 or 4 years cycle. The reasons could be age of the bush, age of the wood, vigour, bush frame and hygiene. Proper identification of these reasons by close observation at the end of every cycle is very important to adopt corrective measures. However, in youngish mature tea after final frame forming prune and in old tea after bush frame rectification, a 3 year cycle of LP-DS-UP or LP-UP-UP is more ideal than any longer cycle.

A pruning cycle of fixed duration for all the sections in an estate irrespective of age, vigour and frame condition is NOT conducive to sustained increased productivity and quality. Certainly other factors affecting growth and the market in which the tea will be sold also have profound influence on the choice of a pruning cycle in an estate/part of an estate.

Assuming that all possible efforts for improving the growing condition are taken and improved agropractices are followed. generally 3-4 year pruning cycles can provide better results in the plains and 4-5 years pruning cycles in the hills of Darjeeling.

Recent studies have indicated that 3 year pruning cycles helped sustaining the productivity better than 4 year cycles in the plains of N.E. India. For both productivity and quality LP-DS-UP was found to be advantageous over other cycles in general. Crop sustainability limit of 3 and 4 year pruning cycles for high and low productive teas were studied and found to be limited within 3 repeats. 4 year cycles could sustain for 1-2 repeats only depending on vigour and age of bush, while 3 year cycles could sustain upto three repeats.

Amongst 3 year pruning cycles LP-UP-UP is the most crop oriented while LP-DS-UP or LP-UP-DS or LP-UP-MS are quality oriented. Amongst four year pruning cycles LP-UP-DS/MS-UP is found to better provided this is not repeated more than once.

Need of Judicious Mixture

A suitable combination of above selected 3 and 4 year cycles could be applied according to age and yielding capacity of the sections so as to achieve a good balance of desired percentage area under various cuts in an estate. However, considering Crop Sustainability Limit and quality of tea adoption of 4 year cycles should be minimised.

Need of Bush Frame Rectification

It is essential to examine the bush frame at the end of the suggested period to decide rectification measures as will be necessary. Depending on situation, one may perhaps have to examine the need of :

1. Pruning at appropriate wood.
2. Adjustment on the tipping measure following prune.
3. Bush sanitation measures.
4. Adoption of proper sequence of pruning.
5. A suitable 3 year cycle may be adopted with due consideration of the total area of the estate to be allocated under different cuts in a planned manner.

QUALITY REQUIREMENT

Leaf from unpruned tea by and large is inferior in quality than that of pruned or deep skiffed teas and this is reflected in the made tea quality. However, if plucking round and standard of plucking are maintained properly and enough care is taken in the factory, deterioration of quality can be minimised to a great extent.

Pests and diseases : Red spider and other mites, helopeltis and black rot are the major pests and diseases having direct bearings on tea kept on a longer pruning cycle. Mites thrive on the old foliage during winter and start multiplying next season as soon as the weather warms up. The residual population is directly related to the amount of foliage left at the time of pruning/ skiffing. Therefore, skiffed or unpruned tea is more prone to red spider and other mites. If an estate decides to have large area of unpruned/skiffed tea, then it should be prepared to face a more serious problem of mites. Similarly unpruned and light skiffed teas are generally found to bear higher incidence of helopeltis and thrips.

It is advisable not to go in for unprune, light or medium skiff in sections which are badly affected by black rot. Such sections should preferably be pruned or deep skiffed and extensive spraying should be undertaken for controlling black rot. Once the black rot is fully under control, the sections can be switched over to a longer pruning cycle.

Climate and soil : Climate and soil of a region also affect the choice of a pruning cycle. The two important elements of climate are rainfall distribution and temperature. Light textured soils have low moisture storage capacity and are more drought prone. It has been experienced that unpruned or light skiffed teas suffer more from drought because of a higher load of foliage they carry on. Regions with prolonged drought like Cachar, Terai and parts of Dooars and North Bank have to take this point into consideration. But even in these areas pruning cycles incorporating unpruned years have been followed successfully. However, if drought prone areas wish to introduce unpruned years in their pruning cycles, then good-shade must be ensured in the unpruned sections. Good weed control, particularly during October to April, will also help in conserving moisture lost by transpiration through weeds.

Crop distribution : Pruning and skiffing can be profitably utilised to obtain increased crop from the existing field, i.e. by careful admixture of various forms of skiffs and prune in any tea estates it is possible to increase yield and even out the crop distribution.

Table 3. Percent periodic crop distribution from different forms of prune/skiff.

	Pruned	Deep skiffed	Medium skiffed	Light skiffed	Unpruned
Early season	22	28	32	40	45
Rains	63	63	61	55	52
Back end	15	9	7	5	3
Total	100	100	100	100	100

... distribution of crop from different pruning/skiffing is shown in Table 4.

Table 4. Percentage distribution of crop from different forms of prune/skiff.

Type of prune/skiff	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
LP	-	1	5	11	15	16	20	20	11	1
DS	-	3	9	11	17	18	18	15	9	-
MS	-	6	11	12	17	17	16	13	8	-
LS/UP	9/10	9	11	11	15	12	13	13	6	-

However, both monthly and flushwise distribution can vary under different agroclimatic conditions and under different field management practices. The seasonal crop distribution patterns for 2-4 years pruning cycles are shown in Table 5.

Table 5. General seasonal crop distribution from some pruning cycles (in %).

Pruning cycle	Early season crop	Main season crop	Back end season crop
2 years cycle LP(50%)- UP(50%)	34	57	9
3 years cycle LP (33%) - UP(33%) -DS(33%)	32	59	9
4 years cycle LP(26%) - UP(25%) - DS(24%) - UP(25%)	35	57	8

Labour availability : Unpruned/light skiffed teas require approximately 30-40 per cent higher mandays for plucking compared to pruned or deep skiffed teas. Estates having problem of labour shortage should also consider this aspect when finalising a pruning policy.

Response from various skiffs and unprune : With tea of normal vigour, generally higher yields are obtained with lighter cuts over light pruning. The average percentage increase in crop with different forms of skiff and unprune over light prune is as follows :

Deep skiff	: 10 - 15 per cent
Medium skiff	: 15 - 20 "
Light skiff	: 20 - 25 "
LOS/Unprune	: 30 - 35 "

EFFECT OF HEAVY PRUNING

Rejuvenation implies restoration of young age by removing the inhibition of old age. In practice this is done by :

1) Removing as much of the unproductive bush frame as possible by pruning at a low height.

2) Thorough cleaning out of the remaining portion of the bush of all diseased and damaged parts.

3) Creating conditions favourable for quick regrowth of shoots and absorbing roots.

4) Restoring plant density by infilling

Even in the year of rejuvenation pruning, fertilizers should be applied five to six months ahead of pruning. Prior to pruning, the section should be rested to build up carbohydrate reserves. Resting for a minimum of two months should be done from end October.

Normal rejuvenation and rejuvenation with interplanting raised yields by 24 and 47 per cent respectively in the 7th year from rejuvenation pruning (Fig. 5). Thus, rejuvenation has been effective in arresting the deterioration of old sections of tea and

raising their productivity. The pay-back period for rejuvenation has also been found to be lesser than that of replanting (Anon. 1981-82). But rejuvenated sections are unlikely to remain economically viable for long because of the presence of old bushes and planting of infills in unrehabilated soil. Still, rejuvenation can serve useful purpose by improving temporarily the economy of an estate where land for extension planting is not available. Replanting in such cases can possibly be undertaken at a smaller proportion to start with and then increased gradually.

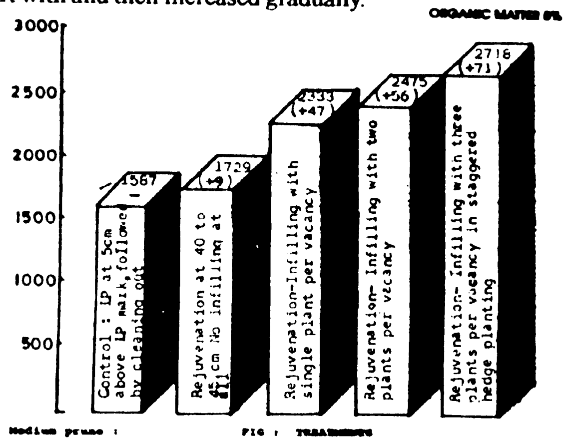


Fig. 5. Yield response from rejuvenation and infilling; yield in KMTH and per cent increase over control are given on the top of each bar.

MEDIUM PRUNE

Recovery potential from pruning varies with jats. In Assam kind of bushes it was found that medium pruning between 50-70 cm produced higher yields than at lower measures. A China plant is naturally a dwarf plant and does not grow to a height more than 4-5 m whereas the Assam type grows to a height of 10-12 m. This difference in growth habit was reflected in the pruned and plucked tea in that maximum yields were obtained in China when pruned at a lower height.

OTHER POINTS

Leaving Breathers

Leaving at least two 'breathers' (lung shoots) in South-West side of the bush has the following beneficial effects.

1) Provide shade to reduce sunscorch.
2) Remove harmful metabolites from the roots.
3) Mobilize growth substances towards the production of new shoots.
4) Contribute photosynthates to the roots.
5) Influence the growth of feeder roots.

If, however, the medium pruning is done at a time when the starch reserves are optimum, no additional benefit would be obtained by retaining lung shoot in the year of prune or in subsequent years. Lungs left on the bush should be cut back after the new flush of shoots on the bushes has produced some leaves.

Deep Skiff

When done after a light prune, this is a cut given midway between the pruning and the tipping levels. For instance, tea tipped at 20 cm will be deep skiffed at 10 cm above the previous pruning level. Deep skiffing after one or more years of unprune or level skiffs is a cut midway between the pruning level and the height of the table at the end of the season. This height normally comes at 12.5-15 cm (maximum) from the last LP mark. At this level, a fork each in most of the primaries is available thereby ensuring higher crop.

Medium Skiff

When done on light pruned tea tipped at 20 cm or deep skiffed tea tipped at 10 cm, this will be a cut at a height of 15 cm from the pruning mark or 5 cm below the last tipping level. However, when medium skiffing is done after one or more years of unprune, light skiffed or level skiffed years, this skiff is given just below the 'Crow's feet' formed by the last year's plucking.

Skiffing of Tea in Growing Season

1. Skiffing should be done at the last plucking height.

2. After skiffing the tea should be plucked on a weekly round.

3. In order to keep the crop loss to the minimum, skiffing should be completed as far as possible before the first week of September in plains estates and the 15th August in Darjeeling.

4. If the tea remains unplucked for two to three weeks for reasons beyond one's control, it will normally be advisable to skiff it as soon as possible at the height of the last plucking and follow this by plucking on a weekly round.

5. In Darjeeling, where it is not possible to pluck the banjhis between flushes on unpruned or light skiffed tea in the third or fourth year of the cycle, skiffing can be done to remove the banjhis immediately following a round of plucking.

Size of Knife

Fifteen cm blade knife should be used for light pruning of youngish tea. For cleaning out operation, a smaller knife of 7.5 - 10 cm should be used.

Weight of knife used for CA pruning should not be lesser than 450 g. Lighter knives cause wood splitting.

MANAGEMENT OF INFILLS

J. Chakravartee and S. K. Pathak

With advancement of age the vacancy in a tea section increases due to many reasons. At times it becomes a major factor responsible for yield reduction. Increased weed infestation, decreased pluckers' productivity etc. are associated problems with high vacancy. As soon as the yield of section goes down below the average yield of the estate, it becomes a burden on other high yielding sections. So, consolidation of such an area by infilling and/or interplanting is necessary to increase the productivity of the section provided the death of bushes is not due to infection of primary root diseases and/or acute waterlogging condition.

SELECTION OF SECTIONS FOR INFILLING

To select a section for infilling the following points are to be considered :

1. Section due for uprooting within next 10 years should not be considered for infilling.

2. The existing tea should not be affected by primary root diseases. However, if infection is confined to a particular patch only, the area may be isolated by digging a trench surrounding it and treating it separately as recommended in T.E. Sl. No.70/1 filed under J-3 to control primary root diseases. The remaining area may be infilled.

3. The collar region of the existing bushes should reasonably be healthy and in good shape, i.e. it must not be badly damaged by termite and/or poria.

4. Section with more than 25 per cent vacancy should not be selected. However, in hilly areas infilling is advised with vacancy more than 25%.

5. Infilling should be undertaken only after improvement of drainage system.

6. Closely planted single or double hedge tea need not be infilled after the final frame forming prune unless more than one vacancy occurs in a place.

LAND PREPARATION

It is always desired that the vacant patches of the selected sections are kept under rehabilitation crop like Guatemala grass at least for two years before infilling. Rehabilitation crop can be planted in the year of light prune of the preceeding cycle. In that year, just after pruning, all the dead and moribund bushes should be uprooted along with all the roots followed by deep hoeing. The drainage system should be checked and improved if necessary. Ground should be levelled thoroughly by flattening the drain sides, filling in the depressions around the collar region of the bushes and the saucers. Thereafter, Guatemala should be planted in the vacant patches and lopped periodically depending on growth. At the end of the above cycle, tea should be medium/light pruned within 50-65 cm ground measure, i.e. just below the general level of the knots. Pruning at a lower height of 40-45 cm ground measure is beneficial if interplanting is done. In hilly areas, it is done at 25-37 cm for large leaf hybrid and Assam kinds and at 15-20 cm for multistemmed chinary types.

INFILLING OPERATION

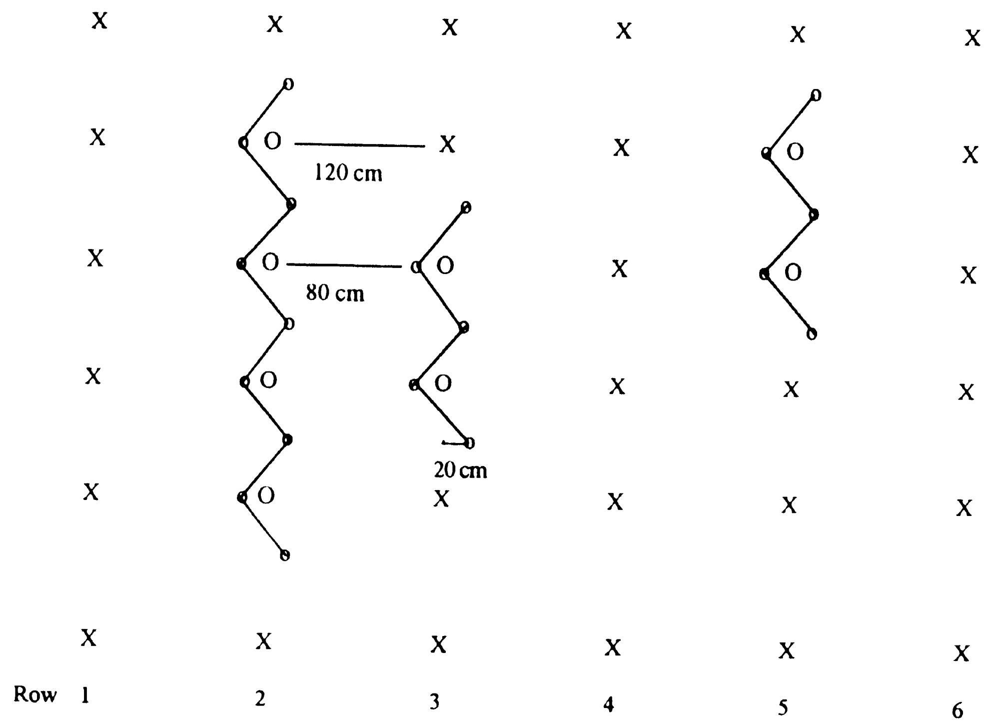
Time of Infilling

Infilling should be done in the year of heavy prune preferably during spring, i.e. April to June when the soil is adequately moist after a few showers. Heavy rainy days should be avoided. In non-droughty areas and droughty areas with irrigation facilities infilling can be done in autumn also.

Planting Pattern of Infills

Single vacancy should be infilled by planting 3 plants, one in the middle and two on both sides of it.

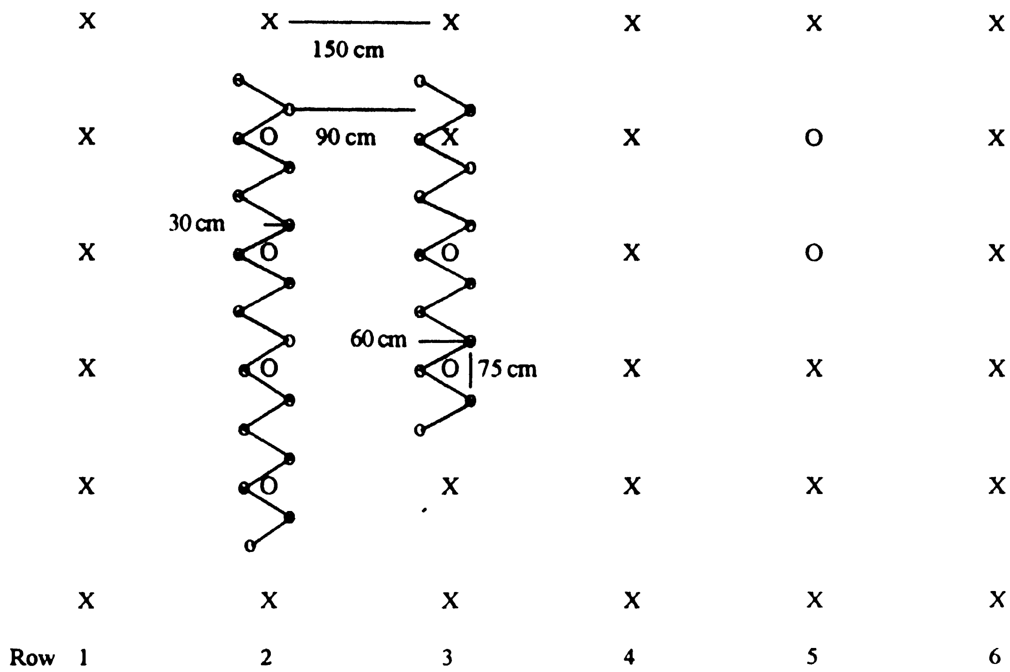
If vacancy is more than one in a continuous strip with wide spacing like 120 cm x 120 cm, the number of infills should be double the vacancy plus one and planted in a zigzag manner slightly away (20 cm) from the original line of planting on both the sides (Fig. 1).



Spacing : 120 cm X 120 cm
No. of infills : (2 X vacancy) + 1
X = Existing bushes
O = Vacancy
o = Infills

Fig. 1. Infilling in a zigzag manner.

When the plucking gulli is still wider with spacing like 150 cm x 150 cm or 150 cm x 120 cm or 150 cm x 60 cm, infilling can be done in staggered double hedge manner along the vacant strip. The spacing within the hedge should be 60 cm and plant to plant in rows should be 70-75 cm (Fig. 2). In this situation the number of infills is more than 4 times the number of vacancies.



Spacing : 150 cm X 150 cm
No. of infills : (4 X vacancy) + 1
X = Existing bushes
O = Vacancy
o = Infills

Fig. 2. Infilling in a double hedge manner.

Interplanting

In case of wide spacing (120 cm x 120 cm, 150 cm x 150 cm etc.) a new plant can be planted in between two old plants along the rows and thus converting it to a spacing of 120 cm x 60 cm or 150 cm x 75 cm. This will increase the plant population upto double of the original number per unit area. The approximate requirement of new plants in different spacings is shown in Table 1.

Table 1. Requirement of plants for interplanting.

Old spacing	New spacing	No. of plants required/ha*
120 cm x 120 cm	120 cm x 60 cm	6944
120 cm x 150 cm	120 cm x 75 cm	5555
150 cm x 150 cm	150 cm x 75 cm	4444

* The actual number will be around 5% lesser than the calculated one.

Plants for Infilling

For infilling the plants should be healthy and 12-18 months old with a minimum height of 60 cm. Vigorous clones like TV19, TV20, TV22, TV23, TV25, TV26 and Seed stocks like TS462, TS463, TS464 etc. should be preferred. If the plants are too tall and unmanageable in planting, they may be skiffed at 50-60 cm height just before planting in the field.

Pit Size and Handling of Plants

The pit size should be adequate with a diameter of 45 cm and depth of 45-60 cm. The bottom soil should be loosened further upto 15 cm. Young plants selected for infilling should be lifted with large 'bheti' (when grown on bed) without exposing the roots. Sleeve grown plants should carry the mother soil intact with undamaged root system. If required, overgrown roots at the bottom of the sleeves can be cut with a sharp knife. Likewise, top growth can also be skiffed at around 50-60 cm at the time of planting in case of over grown plants.

Manuring in Planting Pit

The dose and procedure of manuring in planting pit is similar to that of young tea planted in a new area.

BRINGING UP OF INFILLS

Mulching

After planting the young plants should be mulched with cut leafy jungle or thatch to prevent moisture loss. Mulching is important particularly when planting is done during autumn. The mulch material should be kept slightly away from the collar to avoid heat injury and termite infestation.

Shade

Shade rehabilitation should be done where necessary. Old and diseased shade trees should be ring-barked two years before heavy pruning followed by felling in the prune year. The stumps should be removed with roots. Quick growing, temporary shade species like Ghora neem (*Melia azedarach*), *Albizzia chinensis, Indigofera teysmanii* and *Leucaena leucocephala* can be planted in a mixed stand at close spacing of 5 m to 6 m square.

Weed Control

The ground of infilled area should be kept clean through hand weeding. Herbicides can also be applied to control weeds in between the rows as mentioned below.

Pre-emergent herbicides	- Simazine (1:200) or Oxyfluorfen (1:400)
Post-emergent herbicides	- Glyphosate (1:200), 2,4-D and Paraquat (1:400)

While spraying 2,4-D/Paraquat, utmost care is necessary by using protective shield. Simazine should not be applied during peak rainy period.

Manuring

Infills should be treated as young tea in respect of manuring. NPK mixture 2:1:2 or 2:1:3 (where soil potash status is below 100 ppm) should be applied in ring method slightly away from the collar at 6-8 weeks intervals. Table 2 gives a broad guideline on the dose of manure to be applied during the initial years.

Table 2. NPK mixture (2:1:2 or 2:1:3) per infill.

0 year	1st year	2nd year
30 g in two applications of 15 g each	80 g in four applications of 20 g each	100 g in four applications of 25 g each

From 3rd year onwards general dose of manuring can be recommended as broadcasting in the section including young and old bushes. As such, no separate manuring will be necessary for the infills.

Manuring of rejuvenated and medium pruned old tea should be done with NPK 2:1:2 or 2:1:3 mixture at rates given in Tables 3 and 4 respectively.

Table 3. Manuring of rejuvenated tea.

Pruned year 1st year	UP year 2nd year	LP year 3rd year
100 gm in 2 applications of 50 gm each	160 gm in 2 applications of 80 gm each	160 gm in 2 applications of 80 gm each

From 4th year onward normal dose of NPK as recommended for mature tea can be applied.

Table 4. Manuring of medium pruned tea in MP and UP years.

Yield KMTH (average of preceding cycle)	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha
1500	90	45	135
1501-2000	100-110	45	150
2001-2400	110-130	45	150

At the end of unpruned year tea will be light pruned and thereafter a normal pruning cycle will be followed. Manuring in the first normal cycle should be done on the basis of average yield of the MP and UP years as recommended for mature tea.

PRUNING

1. The infills should be thumb pruned, debudded or decentered (in presence of laterals at lower level) at 30-35 cm ground measure during July-August of the year of planting.

2. Side laterals should be allowed to grow and tipped at the same level as old bushes.

3. Along with heavy pruned old teas, the infills will also remain unpruned for one year. During April-June of the unpruned year, the strong and criss-cross branches at the center should be removed to encourage the spread of the frame.

4. At the end of the unpruned year the infills will receive a cut-across at around 45-50 cm and recentered if required. The old bushes should also be pruned at 7-8 cm above the last pruning level. Tipping should be done at the same level as old bushes.

5. In initial years the side branches of old bushes should be trimmed judiciously to make room for the infills to develop. One trimming during August-September in the year of infilling and another during May/June in the next year are normally sufficient.

6. Areas created vacant by dead infills should be replanted during October-December in the year of infilling.

Schedule for bringing up of infills is given in Table 5.

Table 5. Bringing up of infills.

Year	Period	Operation of infills	Operation of old bushes
0 Yr	Apr-Jun; under irrigated condition infilling can be done before Apr.	Transplant the infills and allow them to grow to establish fully.	Medium pruned at 50-65 cm ground measure during preceding cold weather,i.e. Dec-end Jan. Tip at a higher measure i.e. 30-35 cm above the pruned level.
	Jul-Aug	Decentre at 30-35 cm and tip the laterals at the same level as medium pruned bushes (any where between 85-90 cm). The side branches of medium pruned old bushes should be judiciously trimmed to allow space for the infills.	
	Oct-Nov	Repeat transplanting in the vacancies created by dead infills and also where the old bushes failed to recover from heavy pruning. They should be decentered and tipped during Mar-Apr of the following year.	
+1 Yr	Apr-Jun	Head back/remove strong central and cross branches upto 35-40 cm ground measure. Continue plucking the infills at the same level as old bushes.	Unprune/level off skiff/light skiff/ medium skiff.
+2 Yr	Jan	Cut across at 45-50 cm and tip at the level of old bushes.	Light prune at 7-8 cm above medium prune level and tip over 25 cm.

Afer that, the general pruning cycle adopted by the estate can be followed.

BLOCK INFILLING

In case of large vacant patch there can be done block infilling. The area should be squared.up by uprooting the old bushes, if necessary, followed by land preparation by hoeing or ploughing wherever possible. Rehabilitation can also be done by growing *Mimosa* or *Guatemala* for two years prior to infilling to improve the soil structure and organic matter. After that tea should be planted and brought up like young tea.

PLUCKING - IMPORTANT CONSIDERATIONS UNDER VARIOUS SITUATIONS

J. Chakravartee and A.C. Barbora

Continuous removal of the vegetative organs at short intervals by plucking and at long intervals by pruning are unique features of tea culture.

Plucking provides stimulus and ensures regeneration of shoots on a tea bush, but at the same time it is also the harvesting operation. A delicate balance must, therefore, be maintained between the immediate gain and the capacity of the bush to generate new crop of shoots.

The following are the main objectives of a good plucking policy in an estate :

1. Harvest of maximum shoots for manufacture.

2. A grand mix of yield and quality.

GRAND MIX OF YIELD AND QUALITY

- Planting material with yield and quality potential
- Shoots with increased dry matter
  - Plucking according to leaf period
  - Leaving uniform standard of sinks
- Human and climatic factors

The subject of plucking can be discussed under the following heads :

1. Maximisation of harvest
2. Plucking system
3. Standard of plucking
4. Plucking round
5. Creep and breaking back
6. Banjhi shoots
7. Mechanical harvesting
8. Plucking under extraordinary situations

MAXIMISATION OF HARVEST

Role of Maintenance Foliage

All mature leaves left on the bush below the plucking surface are the maintenance leaves. The growth of harvestable shoots is dependent on the maintenance foliage. This lower layer of leaves manufactures carbohydrates which are translocated to the growing shoots. Photosynthetic efficiency of the maintenance foliage is retained for about six months after which it gradually declines and the leaves ultimately drop off after about 18 months.

In a tea leaf the capacity of manufacturing food material develops gradually and a leaf does not attain full physiological efficiency until it has grown to half of its full size (about three weeks from unfolding of a leaf). Even the third leaf on an actively growing shoot imports photosynthates from the maintenance leaves.

Young shoots on a plucked bush are, therefore, produced initially at the expense of food manufactured by the maintenance leaves. Young shoots on a plucked bush are removed fast, and their constant removal stimulates production of new shoots at such a rapid rate that the bush can be deprived of the material utilized in their production. Therefore, an adequate number of permanent leaves is essential for sustained productivity and survival of a plucked tea bush.

The depth of maintenance foliage in a tea bush is regulated by the tipping height. The relationship between tipping height and yield is simple in annually pruned tea, because basically the same type of top hamper and depth of maintenance foliage is established every year. In case of longer pruning cycles, the nature of growth of the top hamper and the depth of maintenance foliage change from year to year depending on whether the bush is pruned, skiffed or unpruned.

The canopy of maintenance foliage is the 'source' of carbohydrates and the proliferating and expanding organs of the plant are the 'sinks' or sites for their utilisation. The products of photosynthesis move from the source to the sinks. Radio-tracer studies have shown that the successive crops of shoots developing on the plucking table are the strongest sinks on a plucked tea bush (TES Ann. Rep., 1978-79). Within the shoot, the growing bud is the strongest sink. Sink capacity drops to 70 per cent of the bud in the first leaf,40 per cent in the second leaf and 30 per cent in the third leaf (TES Ann. Rep., 1983-84).

Regeneration of Shoots

Shoots on the plucking table arise from the buds remaining on the stub of a previously plucked shoot (Fig. 1A), from axillary buds (Fig. 1B) and also from what may be termed as non plucked origin such as from the outgrowth of a dormant (banjhi) bud (Fig. 1C).

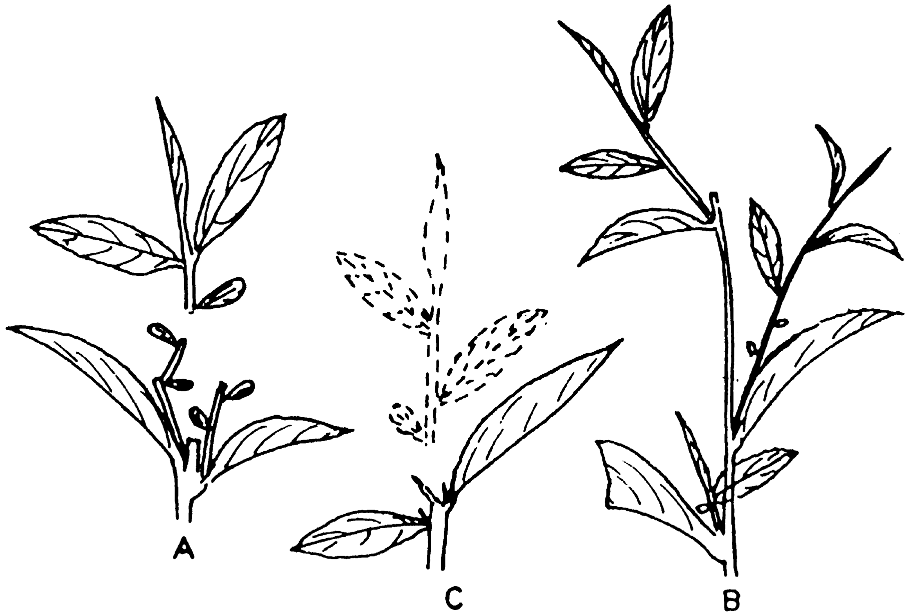


Fig. 1. Regeneration of shoots.

A fully developed bud has the initials of the full flush within it. The bud swells and after a variable period of time it breaks. First the outermost appendage breaks free and produces a cataphyll (janam). This is followed by the unfolding of a second cataphyll (janam). After unfolding of the second janam, the tip of a new leaf becomes visible. This develops into a small blunt leaf with unserrated margin. This is the fish leaf or 'Golpat'. The bud continues to unfold and normal leaves are produced which grow into mature leaves with elongated internodes.

After pruning, primaries arise from the dormant buds on the sticks. These primaries are tipped at a pre-determined height to make a plucking table. Some primaries become dormant below the plucking level. Of these, some remain dormant permanently while others throw out a new flush of growth which comes above the plucking level and is plucked. After a primary shoot has been tipped new shoots arise from the axillary buds (first order laterals) and these shoots are plucked when they grow above the tipping level. Plucking of the laterals again stimulates production of new generation of shoots of the next higher order and the process continues (Figure 1).

Conditions Affecting Shoot Growth

Hereditary character : Jats and clones differ in their rate of growth. The mean number of days taken for axillary buds to develop into 2+B shoots at Tocklai was found to be as follows :

TV1	: 34 days
TV7	: 31 days
TV10	: 38 days
TV15	: 37 days
TV18	: 35 days

Soil fertility : Soil fertility status also influences the shoot growth. When any nutrient is not available adequately, the growth of the plant suffers.

Humidity : The growth rate of the shoot is limited by low humidity. Harler (1922) observed that increase in humidity increased the number of shoots.

Air temperature : On an average, net photosynthesis is maximum at 30°C. Growth was most rapid and leaf size was maximum at 30°C. and growth of shoots ceased below 12.5°C.

Day length : Better growth of tea shoots is generally observed in longer days. Stem length was found to be increased with longer days. Eleven hours 15 minutes was observed to be the critical day length for shoot growth.

Soil moisture : It has been reported that the available water in the soil should not fall below 50 per cent of its field capacity for optimum growth (Grice and Clowes, 1986).

Soil temperature : Correlation was also observed between shoot growth and soil temperature. Some workers reported that raising the soil temperature by mulching from 15°C to 18°C at 7.5 cm soil depth resulted in increased growth and shoot yield.

Leaf temperature : Temperature of fully exposed horizontal leaves is 2°C - 4°C higher than erect or semi-erect leaves. The net photosynthesis declines sharply above 35°C and there is no net photosynthesis between 39°C and 42°C, but respiration continues upto 48°C above which the leaves are damaged.

Factors Affecting Shoot Size

There is an inverse relationship between number and weight of shoots in a tea bush. Shoot size is determined by the following.

Genotype : China variety bushes have more number of shoots but the size is smaller. The opposite is true for Assam variety of teas.

Type of prune : In the year of prune, shoots have the maximum weight but their numbers are minimum. With lighter forms of skiff and unprune, shoots tend to increase in number but decrease in unit weight depending on the severity of skiff operations. Reasons for the decrease in weight are :

1. Internal competition among increased number of shoots.
2. Complex system of branching of the plucking surface.
3. Interference with the movement of water and nutrients.
4. Loss of vigour of apical meristems due to aging.

Shade : Shade has a favourable effect on shoot size.

Standard of plucking : Black plucking tends to increase the number of shoots but weight per shoot decreases.

Tipping Measure

Annually pruned tea showed that initially more crop could be harvested from a low tipping measure, but sustained high yields were obtained with longer tipping measure. From the work done in the past at Tocklai, it has been observed that the best tipping height from the point of view of yield is the natural banjhi horizon of the shoot system on a pruned bush. This height

in a normal bush is 20 cm which corresponds to five leaves on an average. However, the average height of five leaves may vary between 15 cm and 30 cm depending on the type of tea, its vigour and the thickness of the wood on which pruning is done.

The number of primaries on a bush reaching the tipping level decreases and the number of leaves per primary increases with the rise of tipping height. Excessive rise of tipping height reduces the number of pluckable primaries out of proportion though yield per primary increases. The proportion of early season crop increases with the lowering of the tipping height. The weight of shoot decreases and the number of banjhi shoots increases with the reduction of the tipping height.

The maximum number of shoots making 50-55 per cent of the total yield are generally harvested from the uppermost first order laterals. The number of shoots plucked from the first order laterals of second, third and lower leaves diminishes in proportion to the distance of the lateral from the point of tipping.

1. The top 10 cm layer of maintenance foliage consisting of 2-3 leaves is physiologically most efficient and contributes towards 75 per cent of the total crop.

2. The remaining foliage in the lower hamper contributes towards 25 per cent of the crop and also supports the branch system of the top hamper.

Regeneration of Laterals

In course of the plucking season a maximum of eight orders of laterals can be produced in pruned bushes when tipping height is 15 cm and above. For every shoot of 1st order lateral produced there are on an average two shoots of the second order. If this rate is to maintain, there will be four shoots of the third order, eight shoots of the fourth order and so on. But in actual practice, multiplication of shoots at the plucking table from successive order of laterals drops in the order of 2.0, 1.5, 1.2, 0.8, 0.4, 0.2 and 0.1 in course of the growing season. From physiological and agronomical studies at Tocklai, the following important observations were made.

1. Low tipping can increase yield for a period of say maximum of 10 years in annually pruned tea.
2. Stepping up by 10 cm in July after an initial tipping measure of 10 cm results in loss of total crop in the year of stepping up. The thickness of primaries is also affected adversely.
3. There is apparent vascular connection between first and fourth leaves, thereby facilitating the flow of food materials from fourth leaf to the shoots subtended by first leaf.
4. Fish leaf (Golpat) is photosynthetically very efficient. On area to area basis, its efficiency is about double that of a full grown foliage leaf. Hence there is scope of using fish leaf for raising plucking table against a normal leaf.
5. Fifteen cm or lower tipping did not sustain increased yield except in short internodal clones like TV9 in a longer pruning cycle.
6. The top layer of the canopy contributes maximum towards productivity although all the maintenance foliage (five leaves) contribute their assimilates during peak growing season.
7. In one of the trials at Tocklai with initial low tipping at four-leaf measure and then stepping up by a leaf after 10-12 rounds of plucking produced higher yield in a longer pruning cycle. The long term effects will be known in due course.

Disadvantage of Low Tipping

1. Thickness of primaries reduces proportionately with the reduction of tipping height (Table 1).

Table 1. Effect of height of tipping on the thickness of primary.

Tipping height in cm	Mean thickness of primary in cm
15	0.582
20	0.592
25	0.625
30	0.665
35	0.693

2. Orders of laterals are reduced. As against 7-8 orders in high tipping, only 6-7 orders of laterals can be expected by low tipping under ideal conditions.

3. Inclusion of deep skiffing following a low tipping becomes difficult as it does not provide adequate margin of new wood.

Deep Skiff : In deep skiffed tea, the correct tipping height is the average height of two leaves and may vary between 7 cm and 10 cm.

Medium skiff/unprune : For medium skiff, the tipping height of one leaf will vary between 4 cm and 5 cm. Light, level off skiffed and unpruned teas should be plucked close to janam or to the level.

PLUCKING SYSTEM

The most common system of plucking usually practised in N.E. India is the janam plucking which precludes the formation of any foliage above the tipping level. Large number of trials carried out on pruned bushes invariably proved the superiority of janam plucking over fish leaf plucking. 'Step-up' or 'single leaf' plucking for a few rounds may be beneficial under special situations.

STANDARD OF PLUCKING

Standard of plucking denotes the type of shoots harvested. Two standards of plucking are generally followed viz. 'black' and 'standard' (Table 2).

Table 2. Standard of plucking.

Plucking standard	Type of shoots to be plucked
Black plucking	All 1+Buds, all 2+Buds and single banjhis
Standard plucking	Large 1+Buds, all 2+Buds, all 3+Buds and single banjhis

Experimental results have proved that as a long term policy standard plucking is superior to black plucking for tea in the plains of N.E. India. The results of experiments on black and standard plucking are presented in the Table 3 and Table 4.

Table 3. Effects of two standards of plucking on yield (KMTH) under different pruning/skiffing operations (average of seven experiments over four years).

Standard of plucking	LP	DS	MS	UP	Mean
Black	1627 (5)	1905 (9)	2010 (6)	2240 (4)	1946 (6)
Standard	1707	2083	2147	2335	2068

Note : Figures in parentheses indicate per cent decrease over standard plucking.

Table 4. Effects of standard plucking on production of dry matter and its partitioning into different plant organs.

Plant organs	Annual dry weight (in kg/ha)	
	Black	Standard
Plucking	2024	2140
Pruning	3597	3623
Frame and root	1737	1741
Total	7358	7504

The growth of buds in terms of weight increment as well as in terms of length of shoot is given in Table 5.

Table 5. Mean weight and length of shoot.

Week	Mean fresh weight of shoot (in g)	Mean length of shoot (in mm)
1	0.015	7.0
2	0.022	10.0
3	0.040	15.0
4	0.057	15.4 (Small one and a bud)
5	0.488	27.9 (Two and a bud)
6	1.311	47.9
7	1.980	68.8

It can be seen that by leaving the shoots for seven days between 4th and 5th week, an increase in weight to a tune of eight times could be achieved. This observation suggests that very small shoots should not be plucked.

Sink Capacity of Growing Shoots

Growing bud is the strongest sink amongst the shoots and the sink capacity decreases gradually as the leaves unfold. Taking growing bud as 100 per cent, the sink capacity of 1+bud, 2+bud and 3+bud shoots was estimated as 74 per cent, 36 per cent and 33 per cent respectively. Bud and 1+bud should be retained on the plucking table to reap the full benefit of sink induced photosynthesis of maintenance leaves. The results are shown in Table 6.

Table 6. Relative sink capacity (in percentage) of developing tea shoots of an Assam clone.

Shoot	Spring	Autumn	Mean
Only bud	100	100	100
1 + bud	77	72	74
2 + bud	33	40	36
3 + bud	-	33	33

The effect of intermittent standard and black plucking was also studied. The plucking season was divided into three parts, i.e. March to May, June to September and October to November. Standard and black plucking were carried out in these periods continuously and intermittently in various combinations. Black plucking either in early or late season appeared to be useful when combined with standard plucking in the main season.

PLUCKING ROUND

Plucking round is the time interval in days between successive plucking operations. It varies from 4-14 days, though seven days round is the most common practice. Plucking should be adjusted to the time interval between unfolding of successive leaves on a growing shoot i.e. leaf period. If the leaf period is four days, then 1+bud shoot of today will become 2+bud within next four days and 3+bud within eight days.

During the main growing season in N.E. India, Wight (1932) observed a mean leaf period of four days in the population of seed grown tea. He suggested for the first time a plucking round of seven days based on the formula of a day less than twice the leaf period (2 x leaf period - 1). The harvest from such a plucking round would consist of a large majority of 2+bud shoots which was found to be true in our later experiments.

Leaf period varies from place to place as well as within the same locality at different periods of the year, if the climate happens to be seasonal. The mean leaf period was observed to be nine days at St. Coombs, Sri Lanka and 9-10 days in Java. The

variation is caused mainly by the temperature differences. During the mid summer month of June when the mean maximum temperature was 32°C and the minimum 25°C, the average leaf period of 12 vegetative clones growing at Tocklai was 5.0 ± 0.4 days, which rose to 8.0 ± 0.8 days in November when the maximum and minimum temperatures dropped to 27°C and 16°C respectively (Das 1984).

Several experiments have been conducted (in plains) on the effect of length of plucking round on yield of tea. In general, a linear relationship between yield and plucking round was observed (Table 7).

Table 7. Effect of plucking intervals on yields (in KMTH).

Plucking interval	LP Increase/decrease over 7 days (%)		UP Increase/decrease over 7 days (%)	
5 days	1897	(-4)	2417	(-5)
6 days	1915	(-3)	2467	(-4)
7 days	1983	-	2558	-
8 days	2070	(+4)	2668	(+4)
9 days	2148	(+8)	2725	(+6)
10 days	2194	(+11)	2818	(+10)
11 days	2307	(+16)	2829	(+11)
12 days	2334	(+18)	3006	(+17)
13 days	2511	(+27)	3147	(+23)

The coarser the shoot above two and a bud, less valuable is the tea. Longer rounds increase the coarser leaf and banjhis; both affect quality adversely (Table 8).

Table 8. Average picture of fresh weight (in percentage) of different kinds of shoots under different plucking rounds with standard plucking.

(a) Pruned tea

Plucking round	July		August		November	
	Fine	Coarse	Fine	Coarse	Fine	Coarse
5 days	89	11	94	6	84	16
6 days	78	22	92	8	78	22
7 days	66	34	79	21	75	25
8 days	62	38	69	31	71	29
9 days	59	41	67	33	70	30
10 days	55	45	57	43	68	32
11 days	43	57	55	45	52	58
12 days	40	60	47	53	45	55
13 days	37	63	33	67	30	70

(b) Unpruned tea

Plucking round	July		August		November	
	Fine	Coarse	Fine	Coarse	Fine	Coarse
5 days	84	16	88	12	64	36
6 days	78	22	80	20	68	32
7 days	74	26	73	27	59	41
8 days	65	35	69	31	57	43
9 days	53	47	67	33	56	44
10 days	50	50	47	53	53	47
11 days	43	57	42	58	48	52
12 days	41	59	33	67	40	60
13 days	30	70	28	72	26	7

The young parts of shoots have the greatest influence on the quality of made tea. The average valuation, percentage weight etc. of different components of shoots are given in Table 9.

Table 9 : Valuation of components of shoots.

Component of shoot	Average valuation paise/kg	Percentage dry wt of the component	Percentage contribution of component to total value
Bud	1138	11.47	18.08
1st leaf	902	20.46	23.75
2nd leaf	504	28.92	21.86
3rd leaf	558	9.76	7.83
Stem	724	15.82	17.41
Banjhi	624	13.57	11.07

Note : The above picture is the average from June to October.

The information available on plucking rounds leads to the following interpretation :

1. The optimal plucking round may differ from clone to clone.
2. Climatic conditions, mainly temperature and day length appear to be the main factors influencing leaf period and hence the plucking rounds.
3. Plucking rounds of shorter duration than the optimal reduce crop.
4. Subject to an upper limit, longer plucking rounds may increase the gross weight of harvest, but it will contain a high proportion of coarser shoot components.
5. Adjustment with the leaf period is the only rational method for working out the most suitable plucking round. Plucking round so determined can give the maximum return in terms of both crop and quality. Optimum length of plucking round may vary depending upon the prevailing temperature and other climatic factors.
6. Recent studies showed a strong relationship of temperature with shoot growth. On an average, a dormant bud requires 389 day degrees to become a pluckable shoot, when other environmental factors like day length, soil moisture and humidity are not limiting. There is scope for further refinement in plucking round under different agroclimatic conditions and in different seasons depending on day degree accumulation.

CREEP AND BREAKING BACK

Undue rise of the plucking table results in loss of crop. To avoid undue creep, it is advisable to pluck close to the janam. Some amount of creep is bound to take place in the cropping months. However, the creep should not exceed the following limits under normal conditions (Table 10).

Table 10. Permissible creep.

	By end July	By end August	By end Oct/Nov.
LP	2.5 cm	3.5 cm	5.6 cm
DS	2.5 cm	3.0 cm	4.5-5.0 cm
MS	2.5 cm	3.0 cm	4.0 cm
UP	2.5 cm	3.0 cm	4.0 cm

Breaking back is generally a wasteful and expensive operation. Longer rounds because of shortage of labour, improper supervision, etc. lead to undue creep. When this happens, breaking back becomes necessary. In unpruned and MS teas, the effect of improper plucking can lead to more loss of crop. If the situation warrants, a very light 'airy skiff' to remove just the topmost banjhis can be given.

BANJHI SHOOTS

Banjhi shoots above the plucking surface present a special problem. If they are not plucked, they tend to make the bush surface uneven. If a single banjhi is left on the surface until the bud starts to grow again, this shoot is normally plucked at a higher level since the stem of such a shoot generally becomes very hard.

Irrespective of initial tipping height in pruned tea, leaving banjhi shoots on the plucking surface until they come through results in loss of crop (about 90 KMTH). This loss is attributed to:

1. Uneven surface resulting in inefficient plucking.
2. Rare production of laterals in such shoots.
3. Hindrance in the metabolic activity of the whole bush.

MECHANICAL PLUCKING

On-going experiments on shear plucking have shown that :

1. It is useful as an aid to tide over difficult situations arising due to scarcity of pluckers.
2. To harvest a particular standard of shoots, the optimum length of plucking round varies during different seasons. Shear plucking at 9 to 11 days interval produces similar crop as that of hand plucking at seven days interval during July to September (Table 11).

Table 11. Effect of shear plucking frequency on yield and quality of the harvest.

Mode	Plucking Interval (Days)	Yield (KMTH)	Shoot harvest (%)	
			Standard	Damaged
Hand	7	2938	66	7
	9	3114	63	10
Shear	7	2637	53	28
	9	2865	59	17
	11	2932	58	14
	13	2827	55	10

3. Pluckers' productivity is found to be maximum in unpruned teas (Table 12).

Table 12. Effect of shear plucking on pluckers productivity.

Plucking		Pluckers' productivity					
		LP		UP		DS	
Mode	Interval (Days)	Green leaf (kg/manday)	Increase (%)	Green leaf (kg/manday)	Increase (%)	Green leaf (kg/manday)	Increase (%)
Hand	7	27	-	25	-	27	-
Shear	9	37	39	37	50	38	38

4. When compared to seven days plucking by hand, the pluckers' productivity increased by 38 - 50 per cent from shear plucking at nine days interval.

PLUCKING UNDER EXTRAORDINARY SITUATIONS

Drought

Unpruned tea suffers most from drought. In case drought prevails early in the season, damage to the bush due to die back of tender shoots and plucking point with defoliation of maintenance foliage can be very severe. 'Step-up' or 'Single leaf' plucking may have to be done under such a situation.

Blister Blight and Pest Attack

In the event of severe blister blight incidence in medium pruned and light pruned teas just prior to tipping and where the weather is also favourable for continuity of the disease, initial tipping could be done at a lower measure so that only mature maintenance foliage is left in the bush below the tipping level. On expiry of the vulnerable weather and on control of the disease the plucking table can be raised to the predetermined level. In unpruned tea showing incidence of the disease, black plucking is essential for removal of tender shoots. In case of thrips and helopeltis attack, black plucking is also desirable.

Severe Hail Damage

In unpruned tea the damage is normally confined to the maintenance foliage at the top hamper. Any pocket created by hail damage should be allowed to fill up and then plucked to the general level of the table. In case of severely affected bushes, the plucking table should be raised by one full leaf/fish leaf.

After recovery from hail damage LP, DS and MS teas should be tipped at the recommended measure, i.e. no additional height is to be provided.

Young tea affected by hail should be plucked at a higher level, i.e. 65-70 cm from the ground level which may be one or two leaves above.

Plucking Towards End of Flush

The length of the growing bud often indicates whether the next flush would be vigorous or not. When the length of the growing buds in majority of shoots appears to be lesser than half of the first leaf, it can be presumed that the next flush will be banjhi one. This is the stage where hard plucking is to be resorted to.

This stage comes towards the end of a flush. In absence of a hard plucking, proportion of banjhi shoots on the plucking surface will increase and the subsequent flush will not be vigorous and dense. If complete banjhi removal is not possible by a usual manual round of plucking, a round of careful shearing can be carried out. Proportion of banjhis on the plucking surface is generally more towards the end of the first flush.

IRRIGATION REQUIREMENT IN TEA

P.K. Bordoloi and H. Goswami

INTRODUCTION

Distribution of rainfall in North East India is highly uneven. During the period from October to February rainfall is scanty and the quantity varies from 5 to 10 per cent of the annual rainfall. In this period average evaporation exceeds average precipitation by 8 to 357 mm. Therefore, conservation and supplementation of soil moisture by irrigation becomes necessary during this period of moisture stress.

In order to assess the benefit derived from irrigation in tea, it is important to understand the optimum water need of the tea plant under various agro-climatic conditions, calculate seasonal deficit of water and to estimate the probable response from irrigation.

USE OF WATER BY PLANT

Roots absorb water and plant nutrients from the soil. Water is absorbed mainly through small roots particularly through root hairs. After absorption by roots, water moves up the plant and into the leaves where it is given off as vapour (transpiration). The transpiration rate is controlled to a limited extent by the openings of the leaves called 'stomata'. Stomata remain open as long as the plant has available moisture and the leaves remain turgid. When the leaves lose turgidity due to insufficient moisture, the stomata are usually closed and transpiration rate decreases. Tea, which is cultivated for its tender shoots, suffers in terms of shoot extension rate through the effect of loss of cell turgor.

FACTORS INFLUENCING TRANSPIRATION

The other factor effecting transpiration rate is climate, which includes sunlight, temperature, humidity and wind. The amount and intensity of sunlight is most important. In general, high temperature increases transpiration, and very markedly so if accompanied by low air humidity. On a calm day transpiration may be lesser than that on a windy day.

WATER RELATION OF SOILS

Soil is a three phase complex system made up of solids, liquids and gases. The mineral portion consists of particles of various sizes, shape and chemical composition. These particles are classified according to the size of the grains as sand, silt and clay which determine the texture of the soil.

The liquid portion of the soil consists of water, dissolved minerals and soluble organic matter which fills part or most of the spaces in between the solid particles. The water is absorbed by plant roots and must be periodically replenished by rain or irrigation for the sustained production of crops. Thus the soil acts as a reservoir for moisture. This reservoir and a knowledge of its capacity are the principal factors governing the frequency and amount of irrigation water to be applied. Soil texture is closely related to water holding capacity or the reservoir of moisture available for plant use.

Soil is a porous material composed of particles of different sizes touching one another but leaving vacant spaces in between. The space not occupied by the particles is known as pore space and for most soils it constitutes 40-50 per cent of its volume. Water is stored in the micro pore space. This stored water or soil moisture is used by the plant and in low rainfall areas should be replenished by irrigation. Therefore, soil-water-plant relationship should be understood to work out the irrigation schedule.

SOIL WATER

Saturation

During and immediately following surface irrigation, the soil below the water surface is nearly saturated. Pore spaces among the soil particles are almost completely filled with water. There is little air present in the soil. In a well drained soil, part of the water will move downward by gravity. This water is called gravitational water or free water. At this point soil moisture tension is '0'.

Field Capacity (FC)

The amount of water retained after drainage of saturated soil is called field capacity moisture. At field capacity, each soil particle is completely surrounded with a relatively thick film of water. The moisture held in the soil against gravity may be described in terms of moisture tension. At field capacity a loam or clay soil retains moisture at about 1/3rd atmospheric pressure, whereas in sandy soil it may be as low as 0.1 atmosphere.

The volume of soil wetted to field capacity by an irrigation will depend upon the dryness of the soil, its texture, structure and amount of water applied. The moisture portion of a drained soil of uniform texture and structure reaches its field capacity two or three days after rain or irrigation, depending upon soil texture. This time period increases if there are layers of soil which hinder the downward movement of water

Permanent Wilting Point (PWP)

Removal of water from the soil by plant roots causes the water film surrounding the soil to become thinner and thinner. Finally a condition is reached where the water is held so tightly by the soil particles that the roots cannot remove it at a sufficient rapid rate to prevent the leaves from wilting. When this condition is reached, the soil is at permanent wilting point. At PWP tea bushes show the signs of decreased growth and the leaf colour changes. The soil moisture tension reaches about 14 to 15 atmosphere. Like FC, the PWP is influenced by the soil texture, i.e. fine textural soils have a higher PWP moisture content than soils of coarse texture.

AVAILABLE MOISTURE (AW)

This is the water above the PWP and FC. Considerable soil moisture is present below the PWP but is held so tightly by the soil particles that plant roots cannot absorb it rapidly enough to prevent wilting. The concept of soil water availability has been a controversial issue for quite some time. Recent research findings show that the actual availability may be the entire range or a part of it, depending on the properties of the plant (i.e. rooting density, depth and rate of extension), properties of soil (storage, conductivity, potential) and also to a considerable extent on prevailing microclimatic conditions which dictate the transpiration rate. Tocklai is working on these aspects to evolve a proper irrigation schedule. Until more information is generated, 50 per cent of available moisture is taken as readily available moisture for working out irrigation schedule.

METHOD OF DETERMINATION OF IRRIGATION REQUIREMENT

Plant water use may be measured or estimated. Direct measurement requires sophisticated apparatus. Therefore, it is usual to rely on indirect measurements like monitoring of soil moisture status, or on estimates based on meteorological observations. Less sophisticated equipment like tensiometer can be used to monitor soil moisture status. However, meteorological observations seem to be the only practical approach for large tracts under tea, but this too demands precise instrumentation. Keeping this in view measurement of evaporation (Eo) from an open water surface will be the best compromise. In fact linear relationships have been obtained between measure of evaporation of Class A USWB Pan with that of potential evapotranspiration based on long term meteorological data of different regions, e.g. South Bank, North Bank, Cachar, Dooars and Darjeeling. The evaporation data when multiplied with crop co-efficient give evapotranspiration. The crop co-efficient is dependent on foliage characteristics, stages of growth, environment and geographical location.

Water requirement may be defined as the quantity of water required by the plant in a given period of time for its normal growth under field conditions at a given place. This water requirement is to be applied at the appropriate time for the benefit of the crop.

The environmental factors determine the potential evapotranspirational pull, the plant factors determine the water requirement for growth, and the soil factors determine the water holding capacity and moisture release characteristics. There are several models available for indirect measurement of evapotranspiration, out of which Tocklai used Penman's and Thornthwaite models for the purpose. The results are presented in Table 1.

Table 1. Estimates of Penman's evapotranspiration (ET).

Region	Oct	Nov	Dec	Jan	Feb	Mar	Apr
South Bank	127	89	68	64	86	135	158
North Bank	128	89	66	64	87	139	153
Cachar	144	111	83	82	108	157	174
Dooars	138	100	76	75	95	150	164

The meteorological parameters recorded daily at the centrally located observatories of the respective areas were taken into account over a considerable period of time to arrive at these results.

Estimate of evapotranspiration loss by water balance method is also done and is presented in Table 2. In this method both atmospheric and soil factors are integrated. Efficiency of both the methods is being determined in a field experiment conducted at Dhekiajuli area. In addition to this the critical soil water deficit (SWD) is also being investigated.

Table 2. Estimates of evapotranspiration by water balance.

REGION	Et in mm						
	Oct	Nov	Dec	Jan	Feb	Mar	Apr
South Bank	122	66	42	35	43	65	84
North Bank	177	65	37	30	42	86	144
Cachar	137	83	48	38	53	97	138
Dooars	105	65	43	36	45	90	128

The irrigation requirement should also take into account the rainfall during the period of moisture stress. In North East India high intensity rain causing surface run-off falls in monsoon. The intensity, duration and rainfall run-off analysis during November to April shows that almost 100 per cent of the rain incident during this period can be taken as effective rainfall from irrigation point of view.

Regional analysis of effective rainfall for different return periods during droughty months was carried out from the long term rainfall records. The difference of evapotranspiration and effective rainfall for this period (Oct to Apr) can be considered as the total irrigational requirement. The distribution of such requirement is given in Table 3.

Table 3. Estimates of irrigation requirement.

Region	Month						
	Oct	Nov	Dec	Jan	Feb	Mar	Apr
S. Bank							
ET, mm	122	66	42	35	43	65	84
Eff. rainfall, mm (1 in 5 yrs)	39	2	0	5	17	18	84
Net irrigation requirement, mm	83	64	42	30	26	47	-
North Bank							
ET, mm	117	65	37	30	42	86	144
Eff. rainfall, mm (1 in 5 yrs)	34	0	1	1	2	12	58
Net irrigation requirement, mm	83	65	36	29	40	74	86
Cachar							
ET, mm	137	83	48	38	53	97	137
Eff. rainfall, mm (1 in 5 yrs)	68	3	0	0	2	19	117
Net irrigation requirement, mm	69	80	48	38	51	78	20
Dooars							
ET, mm	105	65	43	36	45	90	118
Eff. rainfall, mm (1 in 5 yrs)	44	0	0	1	5	5	48
Net irrigation requirement, mm	61	65	43	35	40	85	70

The discussion above gives an insight of the estimation of net irrigation depth to be practised in tea areas. However, another aspect of irrigation is the timing or frequency or interval at which it should be followed.

Field Water Requirement

Field water requirement is given by :

$$FR = \frac{ET - ER}{Ea}$$

where, ET = Crop water requirement
ER = Effective rainfall
Ea = Application efficiency

All the parameters in this equation are discussed earlier. The water resources should be assessed to see whether ample surface storage facilities exist or combination of well and surface reservoirs is required.

Frequency of Irrigation

The irrigation frequency (i) can be expressed as :

$$i = \frac{(p.Sa).d}{Et} \text{ days}$$

Where, p = available soil moisture permitting unrestricted evapotranspiration (fraction)
Sa = total available soil water (mm/m depth of soil)
d = rooting depth (m, can be taken as 90-100 cm for tea under good drainage conditions)

Factors p and d are related to age of plants and to some extent planting material. ET varies throughout the growing season. Therefore, irrigation requirement will vary according to age of the plants as well as on atmospheric conditions of the growing seasons.

Soil Moisture Measurement

Time of irrigation can be determined by judging the soil moisture reserve also. For this purpose measurement of soil moisture becomes necessary. Soil moisture can be measured by resistance meters, electron probe or tensiometers. Out of these equipments the less sophisticated equipment viz. tensiometer can be used for timing of irrigation.

Table 4. Range of soil moisture against the tensiometer reading.

Reading	Range of soil moisture
0.1	Soil is saturated
0.1 - 0.2	Soil is in field capacity range
0.2 - 0.5	Indicates soil moisture available to the plant
0.5 - 0.6	Usual range for starting irrigation
0.6	Moisture stress range

For young tea areas tensiometers should be installed at 20 cm depth in the year of planting, and subsequently lowered every year by 10 cm as the root system develops.

For mature tea, install the tensiometer with its tip down to 90 cm depth below ground surface. It will be desirable to install an additional tensiometer at 1/4th the depth of root zone i.e. at 25 cm to provide information on soil moisture in the most active root zone. When shallow tensiometers indicate suction equal to 0.5 then irrigation should be started.

PATTERN AND PRACTICE OF IRRIGATION

Having put forward theoretical optimum irrigation requirements for either helping to establish young tea in drought prone areas or to obtain increase in yield of bearing bushes, some practical aspects should be discussed as to how and when to irrigate with due consideration to other managerial factors influencing the effectiveness of the irrigation pattern proposed.

Young Tea

The sections of young tea likely to suffer most from drought will be those with low moisture holding capacity. Low capacity may be due to shallow rooting in case of very young plants or it may be due to the type of soil itself as in sandy areas. Thus first priority should be given to the newly planted young tea in the sandy areas and teelas specially with south facing slopes. Attention should then be given to the remainder of one year old tea before applying the same sequence of priorities to second year tea. Irrigation during the critical period of first two years in young plant's life in drought prone areas would produce healthier bushes and it should subsequently survive without further irrigation, provided appropriate moisture conservation practices are followed.

The optimum irrigation regime for young tea seems to be 50 mm to 75 mm (depending upon soil and site) at two weeks intervals. The most critical period for survival of young tea (after autumn planting) is October to January and irrigation should, therefore, start from either second half of October or first half of November latest. As a general guideline irrigation should start when the soil has been dry for one-and-a-half weeks. After the first irrigation, six or seven irrigations should follow depending on the time of first irrigation. Rainfall during November to January should not as a rule influence the irrigation regime unless heavy rainfall of 38-40 mm or so is recorded. After such falls the irrigation schedule may be interrupted for a few days during which equipment can be overhauled. It is important to appreciate, however that the area which was irrigated the day before the rain will need irrigation again in two weeks time and that a delay of 2/3 days will upset the schedule and cause harmful water stress. The same schedule of irrigation can continue until April, but this will not normally be necessary if moisture conservation measures are applied; consequently at the end of January equipments can be moved to the mature tea.

To ensure effective sprinkling the green crop can be lopped to a height of 60 cm at the end of the monsoon and, if necessary, followed by another lopping. The loppings should be used as mulch, thereby effecting a considerable saving in water requirement. Tea should be clean weeded immediately after the last irrigation in January. Two years old tea should be pruned immediately after the last irrigation in January. Clean weeding and mulching as advocated for one year old tea towards end January are also applicable in this case.

Great stress should be laid on mulching in irrigated fields fully recognising the difficulties and work involved. There is no doubt about its efficacy and the expense incurred may well be lesser than the cost of continued irrigation which will otherwise be necessary.

Mature Tea

Maximum response of irrigation is generally obtained in the best sections of existing mature tea areas. For this it will be also essential to correctly identify and remove the other limiting agronomic factors through adopting right management and cultural practices.

The best results are expected to come from irrigating unpruned or early light skiffed teas, normally amounting to one-third of an estate with a three year pruning cycle. Benefits from this will be greater not only because the potential yield response is high, but also because this tea suffers most in the years of severe drought.

Careful tipping is of utmost importance to secure an early and steady yield. Experience indicated that the occurrence of a long banjhi period can significantly lower the effect of irrigation. The most important measure in this connection is an early and optimum supply of fertilisers, which should be given in early February either on ground or added to irrigation water.

The irrigation of mature tea seems to be necessary from October to March/April period as per requirements shown in Table 3. However, depending upon October rain the irrigation can start from November till March/April. The first application in November can be a little more than the estimated field irrigation requirement followed by five more applications (values given in Table 3), each at an interval of three weeks. However, number of irrigations will depend upon the April rainfall and as soon as this exceeds 75-125 mm (75 mm for less drought prone areas and 125 mm for more drought prone area), irrigation can be discontinued. Analysis shows that in severely drought prone years, the fifth application in April may be necessary only in two out of three. As in the case of young tea, irrigation regime should not be interrupted except after heavy rainfall exceeding 38 mm (one and half inches) and then for not longer than 2-3 days.

SPRINKLER IRRIGATION SYSTEM : PLANNING AND DESIGN

P. K. Bordoloi and P. Ghosh

INTRODUCTION

Sprinkler irrigation is the most popular and practical system in tea plantations. It is suitable to almost all the soil textures except for very heavy clay soil, and can be used in wide topographic conditions except in steep slopes of greater than 45 per cent. The water requirement, physical properties of soil and topography which vary from place to place are the important factors influencing the design of the system. The steps involved in planning and designing of sprinkler system are discussed in this lecture.

INVENTORY OF RESOURCES AND CONDITIONS

Map of Area - Shape, Size and Topography

A contour map showing all important topographical features as well as water source(s), power line, possible pumping point(s) are the prerequisites for planning and design of a sound irrigation system. This will help in estimating the length of main and lateral lines, friction losses in the lines, pressure requirement of sprinkler and to determine the size and type of pump and motor/engine.

Water Supply - Source, Availability and Dependability

Adequate and dependable water source(s) which can supply water for entire moisture stress period is an important consideration. Where natural source (e.g. river etc.) is not adequate or difficult to harvest, deep tube well needs to be considered. Area to be covered under irrigation will be guided by the availability of water.

The irrigation water should be chemically suitable, relatively clean and free of suspended impurities so that the sprinkler lines and nozzles are not clogged.

Data on Climatic Conditions, Soil and Crop

Soil moisture characteristics and climatic factors like rainfall and its distribution, temperature, solar radiation, relative humidity, wind velocity etc. influence the consumptive use of water by any crop. Data of these parameters are required for designing irrigation system. The frequency of irrigation is determined from the daily peak rate of consumptive use on the basis of the various climatological data. The rate of water application is limited by the infiltration capacity of the soil. Application at higher rate will result in run off and soil erosion. The approximate values of maximum rate of water application for various soil conditions are shown in Table 1.

Table 1. Desirable rate of water application, mm/hr in 4 most common soil textures under different ground slopes.

Soil texture	Ground slope			
	0-5%	5-8%	8-12%	12-16%
Loamy sand	20	18	15	10
Sandy loam	13	10	8	6
Silt loam	10	9	7	5
Clay loam	8	6	5	4

Of all climatic factors, wind plays a very crucial role in design. The impact of wind on irrigation system is discussed later.

Spacing of Sprinklers and Water Distribution

The irrigation efficiency of sprinklers depends upon the degree of uniformity of water application. The water spray distribution characteristics of sprinklers and their spacing will regulate the uniformity of water application. The spray distribution characteristics of sprinkler heads are typical and change with nozzle size and operating pressure. Fig.1 shows the effect of different pressures on distribution patterns.

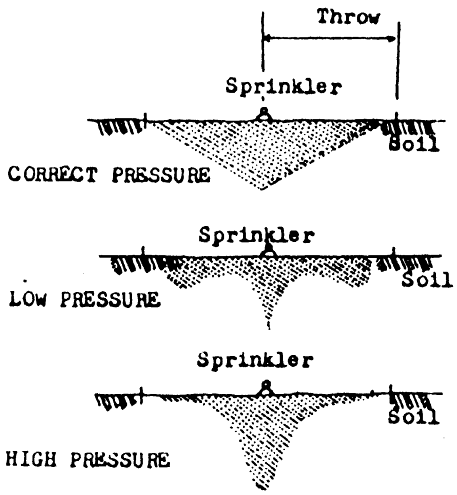


Fig. 1. Effect of operating pressure in sprinklers.

With lower pressure the drops are large and the water from the nozzle falls in a ring away from the sprinkler. With higher pressure the water from the nozzle breaks up into very fine drops and falls near the sprinkler.

A uniformity co-efficient of 85 per cent or more is considered to be satisfactory. To obtain uniformity of water application, the wetted circle of the adjacent sprinklers should be overlapping so as to add water to the area of the adjoining sprinkler. The overlap increases as the spacing of sprinklers decreases. The spacing for high pressure sprinklers can be about 2/3rd of the wetted diameter of sprinkler under no wind conditon. Higher wind velocities distort the distribution as can be seen from Figs. 2 and 3.

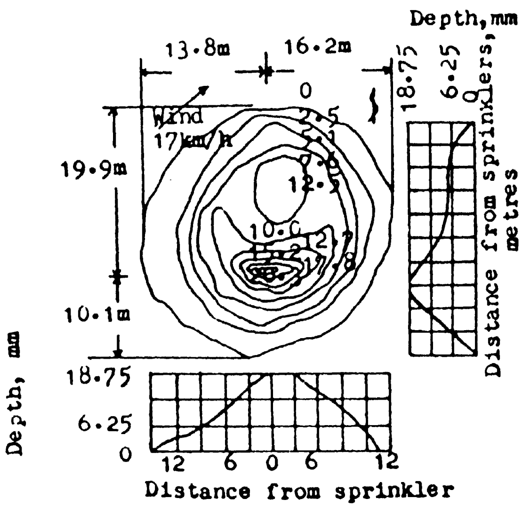


Fig. 2. Water distribution from a sprinkler under unfavourable conditions.

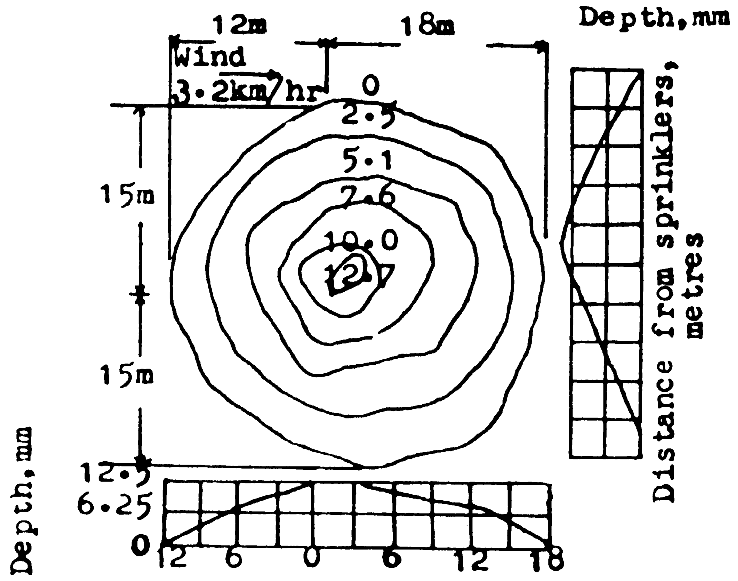


Fig. 3. Water distribution from a sprinkler under favourable conditions.

The overall distribution achieved by overlapping is shown in Fig.4.

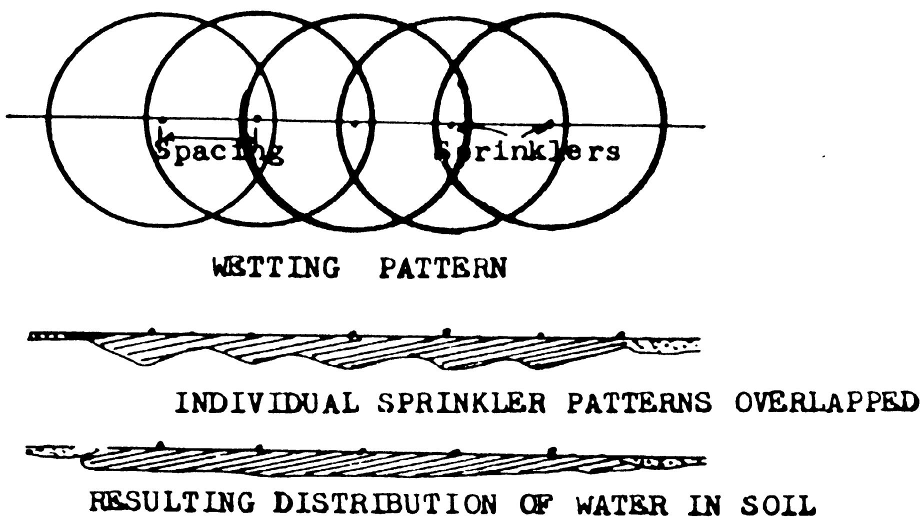


Fig. 4. Wetting and distribution patterns from several sprinklers operating close together.

Table 2 may be used as a guideline to estimate the spacing of sprinklers under windy conditions.

Table 2. Maximum spacing of sprinklers under windy conditions.

Average wind velocity	Spacing of sprinklers
1. 0 km/hr	65% of the wetted diameter of sprinkler
2. 0-6.5 km/hr	60% of the wetted diameter of sprinkler
3. 6.5 - 13 km/hr	50% of the wetted diameter of sprinkler
4. Above 13 km/hr	30% of the wetted diameter of sprinkler

(Source: A.M. Michael, 1989)

The sprinkler nozzle should be evaluated for its application rate and suitability for the soil of the area. The pressure of the nozzle can be measured by a pressure gauge fixed on a pitot tube as shown in Fig. 5.

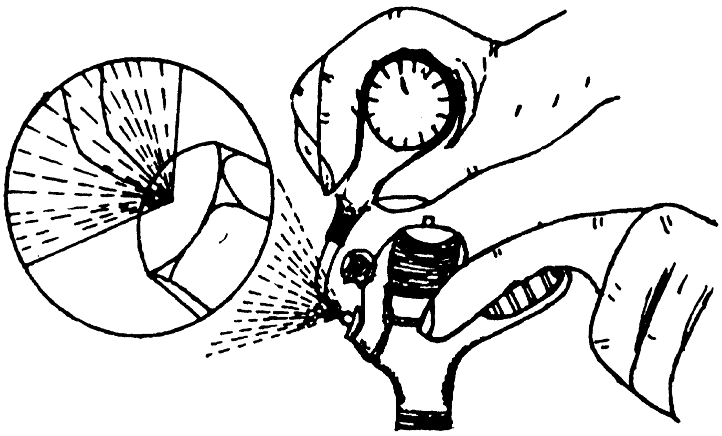


Fig.5. Testing of nozzle pressure by a pitot tube pressure gauge.

An efficient design of irrigation system should also ensure minimisation of run-off, soil erosion as well as crop damage.

Power Source

Electric power is most convenient and economic. The electric pumping sets are cheaper in initial cost and their maintenance cost is also very low compared to diesel engines. However, a standby genset or diesel engine will help uninterrupted operation of the system.

AMOUNT OF WATER TO APPLY IN EACH IRRIGATION

The depth of irrigation is calculated from the total available moisture holding capacity of the soil upto the effective root depth of the crop Most of the roots of tea are generally abundant at a depth of 60-90 cm.

The evapotranspiration pull depletes the available soil moisture gradually which should, in ideal condition, be replenished upto the field capacity level. In many crops including tea, partial replenishment of the soil moisture deficit is made due to economic reasons without affecting the growth of the plant. In calculating the depth of irrigation, the percentage of depletion selected should, therefore, be considered.

INTERVAL OF IRRIGATION/ROTATION

The time interval between two irrigations is normally calculated by dividing the depth of irrigation(cm) by the peak consumptive use of crop (cm/day).

CAPACITY OF THE SYSTEM

The system requirement or the pump capacity depends on the following :

1. Size of the area to be irrigated
2. Gross depth of each irrigation
3. Net operating time required to apply this depth of water
4. Irrigation interval
5. Irrigation efficiency (usually considered at 80 per cent)

The capacity of a system can be calculated from the formula :

$$Q = 27.8 \times \frac{A \times d}{F \times H \times E}$$

in which,

Q = discharge capacity of the pump, litre/sec
A = area to be irrigated, hectares
d = depth of application, mm
F = irrigation interval, days
H = operating period per day, hours
E = irrigation efficiency (percentage say 80)

OPTIMUM WATER APPLICATION RATE

The optimum water application rate depends on soil type, crop cover and slope of the land. Puddling conditions or surface run-off should be avoided. The optimum application rate can be determined by measuring the infiltration capacity of the soil.

SELECTION OF SUITABLE SPRINKLER

The selection of sprinklers depends on the following :

1. Diameter of coverage required
2. Presssure available
3. Sprinkler discharge
4. Wind condition and
5. Soil infiltration and land topography

The required discharge capacity of the individual sprinkler can be calculated from the following formula :

$$q = Sl.\ Sm.\ I/3600$$

in which,

q = required discharge from individual sprinkler, l/sec
Sl = spacing of sprinklers on the lateral line, m
Sm = spacing of laterals on a main line, m
I = rate of water application, mm/hr

Once the required capacity of the individual sprinkler has been determined, a sprinkler with suitable nozzle combination can be selected from the charts provided by the manufacturers. Acceptable combinations are given in Table 3.

Table 3. Operating pressures and nozzle sizes for desired break-up of droplets

Operating pressure	Size of sprinkler	Nozzle size range
60-70 p.s.i.	Equivalent to model ZM-22D (Premier) or Model 6(Voltas)	10mm x 7mm 9/16" x 1/4
50-60 p.s.i.	Equivalent to model 160-ST (Premier) or Model 6(Voltas)	9/32" x 1/8" 3/16" x 1/4"
40-50 p.s.i.	Equivalent to Model 160-ST (Premier) or Model 4(Voltas)	7/32" x 1/8" 7/32" x 1/8"

The sprinkler head is fitted to a riser which should be above crop height. The maximum bush height normally does not exceed 110 cm for mature tea and 80 cm for young tea. The height of the riser pipes should, therefore, be 100 cm and 125 cm for young and mature tea respectively.

SPRINKLER SPACING, NOZZLE, DISCHARGE AND OPERATING PRESSURE

In the first stage an optimum arrangement of the mains and laterals is made in respect to the topography and the operating schedule. For example, if the field has to be irrigated once in 8 days and the lateral is required to be moved twice in a day, then 16 moves are required with one lateral or 8 moves with two laterals.

The spacing and discharge of sprinklers can either be determined by trial and error method or directly using the formula for calculating sprinkler discharge capacity.

Distribution of water from a single sprinkler is not uniform over the entire wetted circle and more amount of water falls near the sprinkler. The depth of irrigation generally decreases with distance away from the sprinklers. To make uniform distribution a generous cverlap of the spray is necessary even under nonwindy conditions.

To attain uniform distribution, the distance between the sprinklers along a lateral line should not exceed 50 per cent of the diameter of the coverage, and the distance between successive positions of a lateral should not exceed 65 per cent of the diameter of the coverage.

Under N.E. Indian tea conditions the European system, i.e. square spacing of the sprinklers, is normally practised. The distance between the sprinklers should be 1.41 times of the radius of wetted circle of a sprinkler (S=R $\sqrt{2}$). The square spacing in European pattern is shown in Fig. 6.

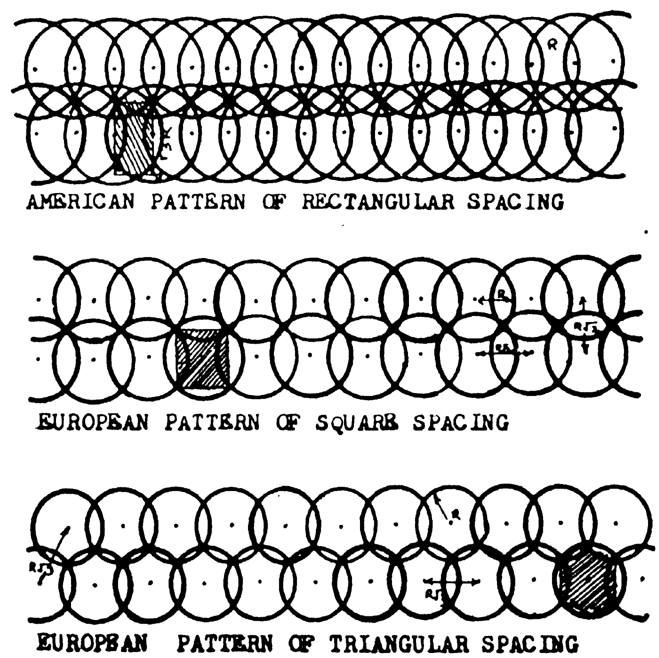


Fig.6. Comparison of American and European patterns of sprinkler spacing

NUMBER OF SPRINKLERS

It is most economical to select widest possible sprinkler spacing. The combinations of lateral shift spacing and riser spacing normally followed are 18m x 12m, 18m x 9m, 15m x 12m and 15m x 9m, etc.

DESIGN OF LATERAL LINES

In the interest of economy and ease of handling, the minimum diameter pipe should be selected consistent with good sprinkler performance. It is recommended that the variation in the pressure in the lateral line should not exceed 20 per cent of the higher pressure. In such pressure difference the nozzle discharge varies by 10 per cent. To design the lateral lines the following steps are followed:

Step 1. Select a given size of pipe.

Step 2. Assume the flow through the entire length without sprinklers and determine the friction loss from standard table.

Setp 3. Multiply loss (2) by the correction factor (from standard table) corresponding to the number of sprinklers on the laterals.

Step 4. Add the elevation if the lateral goes uphill or subtract the drop if the lateral goes downhill to the value obtained in Step 3.

Step 5. Compare the value thus obtained (Step 4)with allowable 20 per cent loss. If it is approximately the same then the selection is correct; otherwise, select another diameter pipe and repeat the procedure. Actually, the design capacity for sprinklers on a lateral is based on the average operating pressure. The average head can be calculated by formula (see Exercise).

MAIN LINE

In contrast to lateral design there are no specific standards as to the amount allowable for main line pipe losses. The function of the main line is to convey the required quantity of water at the desired pressure to all lateral lines under maximum pressure conditions. The selection should be on economic consideration. Usually main line loss of about 3 m for small systems and upto about 12 m for large systems is considered reasonable. For a given discharge rate and head, the size of the main line can be selected from the standard table.

PUMP AND POWER UNIT SELECTION

In selecting a suitable pump, it is necessary to determine the maximum total head or total dynamic head (TDH) against which the pump is working. It is the total head, imposed by the system on the pump under maximum operating conditions. The contributing heads are to be added to get TDH. These heads are :

1. Pressure at the farthest sprinkler on the lateral (minimum lateral pressure + height of riser)
2. Friction loss in the lateral
3. Friction loss in the main line
4. Elevation difference between suction and delivery points at the field
5. Minor losses (friction losses in fittings, valves, tees, bends as well as pump entrance and exit losses)

The amount of water that will be required is determined by multiplying the number of sprinklers by the capacity of each sprinkler. When the total head and rate of pumping are known, the pump may be selected from rating curves or tables furnished by the manufacturer.

The following formula can be used for the determination of the brake horse power :

$$\textbf{Brake horse power (BHP)} = \frac{Q \times TDH}{75 \times Ep}$$

in which,

Q = Pump discharge, lit/sec
TDH = Total dynamic head, m
Ep = Pump efficiency (fraction)

FERTILISER APPLICATOR

The design system of sprinkler irrigation will not be completed if mention is not made about fertiliser applicator. Soluble fertilisers like N, K etc. can be injected into the sprinkler system and applied to tea. This can be done by using a fertiliser tank mounted on the sprinkler line or by adding fertiliser solution through the suction side of the pump as shown in Fig.7.

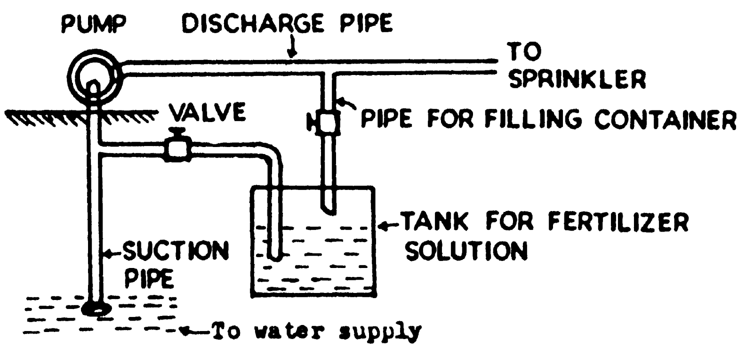


Fig.7. Arrangement of fertiliser injection into sprinkler system.

The quantity of fertiliser to be injected into the system of each setting can be easily calculated from the following formula:

$$N = Ds \times Dl \times S \times F/10{,}000$$

in which,

N = amount of fertiliser required per setting, kg
Ds = spacing between sprinklers, m
Dl = spacing between lateral lines, m
S = number of sprinklers run at a time
F = dose of fertiliser, kg/ha

SYSTEM LAYOUT

The layout or the arrangement of the sprinkler irrigation system is governed basically by the size and shape of the field and the location of the water supply. The arrangement should be such that it will nearly provide the optimum water application rate with the greatest degree of uniformity of distribution. The water source for irrigation may be surface water or tube or open well. For a fully portable system, the ideal arrangement is to have the water supply channel along the middle of the field, lengthwise. The best arrangement, in case of a fixed water supply, is to have the source of water in the centre of the field. If a well is to be drilled for the purpose of supplying water for a sprinkler system, it is best to locate the water well near the centre of the area to be served. Sometimes it may be essential to adopt a sprinkler irrigation system with an already laid underground pipe line water distribution system or field channels. A normal layout system of main and lateral lines is shown in Fig.8.

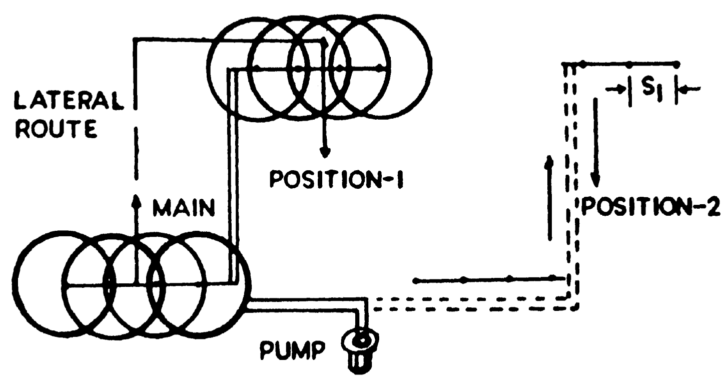


Fig.8. Layout of sprinkler system.

In case of field channels running along one edge of the estate, a portable pumping set and sprinkler unit with the lateral extending to the field may be used to draw water directly from the channel and distribute it through the sprinklers (Fig. 9).

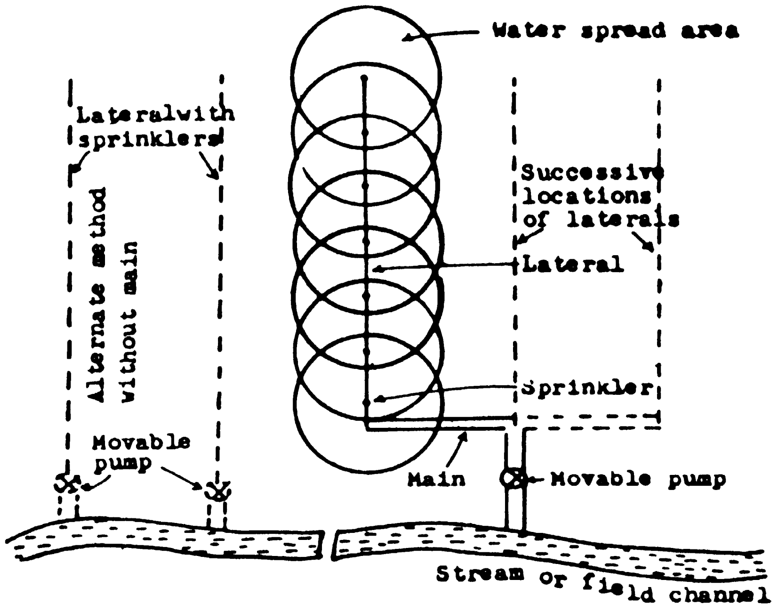


Fig. 9. Typical field layouts for fully portable sprinkler units drawing water from streams or field channels.

Each area will pose different problems, with possibility of a variety of layout and combinations of mains and laterals. The arrangement selected should provide the following :

1. Minimum number of pipes
2. Low labour requirement
3. Uniform distribution of the calculated depth of water in the entire area within the stipulated time
4. Minimum changes of lateral in a day (maximum 3-4 changes in a day)

The following principles are also important in layout of the system :

1. The main line should be located in the direction of the main slope.
2. Lateral lines should be placed at right angle to the main slope or along the contour.
3. Sprinkler laterals should be placed at right angles to the prevailing wind in areas where wind velocities are high. Where steep slopes as well as high winds exist, preference should be given to slopes for layout considerations.
4. Long laterals should be avoided.
5. The laterals should make a complete round to minimise labour requirement and for convenience.

OPERATION, MAINTENANCE AND STORING OF SPRINKLER IRRIGATION DEVICES

A very good design of irrigation system may not work if the operation is faulty. The following points should be looked into :

Operation

1. Prime mover and the pump should be in alignment and at the same height.
2. Laying of pipes should start from pump end.
3. Coupling and rubber seal ring should be clean.

4. Start the engine with the valves closed. After the pump reaches the regulation pressure, the delivery value is opened slowly.
5. Close the delivery valve after stopping the power unit.
6. Dismantling of the installation takes place in the reverse order to the assembly described above.

Maintenance

1. The dirt or sand in the groove in the coupler should be regularly cleaned.
2. All nuts and bolts should be kept tight.
3. When moving the sprinkler lines, make sure that the sprinklers are not damaged.
4. Do not apply oil, grease or any lubricant to the sprinklers. They are water lubricated.
5. Check the washers fitted at the bottom of the sprinkler bearing for wear once a season. Replace, if necessary.
6. The swing arm spring needs tightening after 2-3 seasons' operation.

Storage

1. Remove the sprinklers and store in a cool, dry place.
2. Remove the rubber sealing rings from the couplers and fittings and store them in a cool dark place.
3. The pipes should be placed outdoor in racks.
4. Disconnect the suction and delivery pipe from the pump. Pour in small quantity of medium grade oil and rotate the pump for a few minutes. Blank off the suction and delivery sides. This will prevent the pump from rusting. Grease the shaft.
5. Protect the electric motor from the ingress of dust, dampness and rodents.

Trouble Shooting

A. Pump does not prime or develop pressure

1. Check whether the suction lift is within limits.
2. Check the foot valve, pipes and other connections and flanges for air leaks.
3. Check the strainer of the foot valve for any blockage.
4. Check that the flap in the foot valve is free to open fully.
5. Check the pump gland(s) for air leaks. Use thick grease to seal the gland.
6. Check that the gate valve on the delivery pipe is fully closed during priming and opens fully when the pump is running.
7. Check that the direction of rotation of the pump is correct.

Sprinkler does not turn

1. Check pressure.
2. Check that the nozzle is not blocked. Do not use a piece of wire to clean the blockage in the nozzles.
3. Check that sprinkler bearing is quite free and smooth.
4. Check the condition of washers at the bottom of the bearing.
5. Check that swing arm moves freely. Adjust the swing arm spring tension, if required.

Leakage from couplers or fittings

1. Check that the grooves of couplers are dirt free.
2. Check that the pipe going inside the coupler is smooth, clean and not distorted.
3. Check for the pressure in the line.
4. Check for proper fittings of the materials like bends, tees and reducers into the coupler.

EXERCISE

Design a sprinkler irrigation system for the conditions given below :

Soil texture	: Sandy loam
Depth of root zone	: 90 cm
Infiltration rate	: 15 mm/hr
Land slope	: 0.80%
Wind velocity	: 6.5 KMPH (average)
Source of water	: Deep tube well
Tube well discharge	: 1900 l/minute
Location of tube well	: Factory compound, in the centre of the garden
Elevation difference	: Between lowest section in the south and tube well 5 m
Average height of tea bush	: 100 cm (mature tea)

SOLUTION

Design

Sprinkler model	: Say Premier make, Model ZM 22D
Designed pressure on sprinkler (last one)	: 60 psi (4.2 kg/sq. cm)
Nozzle size	: 9/16" x 1/4" (from manufacturer's chart)
Wetted diameter of this selected sprinkler	= 54.25 m (from manufacturer's chart)
Designed rate of water application	= 15mm/hr
Spacing of sprinkler	: The distance of sprinkler should be 60 per cent of the wetted diameter of spray at 6.5 km/hr wind speed

$$= \frac{60}{100} \times 54.25 \text{ m}$$

$$= 32.6 \text{ m}$$

Let us use square layout.

So, spacing of laterals : 32 m (Say 30 m)

The discharge of individual sprinkler

$$= \frac{30 \times 30 \times 15}{3600}$$

$= 3.75$ lps

$= 225$ lpm

No. of sprinklers required

$$= \frac{1800}{225}$$

$= 8$

Consider 8 sprinklers for two laterals

Length of laterals $= 30 + 30 + 30 + 15$

$= 105$ m

No. of pipes $= 35$

No. of lateral lines in operation	= Consider 2
No. of sprinklers on each lateral	= 4
Total no. of pipes required	= 105 pieces (one line extra)
Total discharge of 4 sprinklers	= 225 x 4 = 900 lpm

Friction loss on lateral line $= \dfrac{1.37}{100} \times 105 \times 0.433$

$= 0.62$ m

The head at the main line (Hn) when laterals are laid on nearly level land

Hn = Ho + Hf + Hr

= 42.00 + 0.62 + 1.25 Ho = 42m

= 43.87m,(say 44m) Hr = 1.25m

Main Line

Size of the pipe for 1800 lpm	= 150 mm (selected)
Pipe material	= Aluminium pipe with couplers
No. of pipe	= Assuming 1200m long plot = 200 pieces (6m long)

Friction loss in main line (Hm) for a discharge of 1800 lpm in 1200 m long line laid up slope from the tube wel calculated as follows.

$$Hm = Lf = 1200 \times \frac{2.12}{100}$$

$$= 24.14 \text{ m}$$

Ht = Hm + Hj + Hn + Hs + He + Hf

= 24.14 + 10 + 44 + 5 + 1 + 4

= 88.14 m say 90m

(Hs=5,He=1,Hf=4)

Pump

Designed discharge rate	= 1800 lpm
Designed pressure head	= 90 m
Pump type selected	= 123 - CM3-1
Suction pipe size	= 150 mm
Delivery pipe size	= 125 mm
Pump efficiency	= 60%
RPM	= 1450

Shaft horse power $= \dfrac{1800 \times 90}{60 \times 75 \times 0.60}$

$= 60$ HP

Electric Motor

	RPM	= 1450
	BHP	= 60/0.95
		= 63
		(Motor efficiency taken as 95%)
or,	Diesel Engine	= Water cooled
	RPM	= 1450
	BHP	= 60/0.75 (Engine efficiency 75%)
		= 80

Area Covered

Let us consider 90 cm soil depth and 50 per cent depletion level for irrigation.

Irrigation requirement = (F.C. - PWP) x 0.5 x B.D. of soil
= (15-8) x 0.5 x 1.6 cm/m depth
= 5.60 cm/m = 56 mm/m
50 mm for 90 cm deep profile

$$\text{Duration of application at one setting} = \frac{50}{15}$$
$$= 3.33 \text{ hours}$$

Assuming 13.5 hours working time/day, area irrigated is calculated as follows :

$$A = \frac{Q.F.H.E}{27.8 \text{ X } D}$$

$$= \frac{1800 - 60 \text{ X } 15 \text{ X } 13.5 \text{ X } 0.8}{50 \text{ X } 27.8}$$

$$= 3.5 \text{ Ha/day}$$

DROUGHT MANAGEMENT IN TEA

M. P. Sinha and T. S. Barman

The stress resistance of plants may be of two types. Elastic resistance is a measure of the plant's ability to prevent reversible or elastic strains (physical or chemical changes) when exposed to a specific environmental stress for example, temporary wilting or drooping of newly unfolded leaves. Plastic resistance is a measure of its ability to prevent irreversible or plastic strains injurious physically or chemically. When the limit of plastic resistance is crossed, scorching of top leaves and tender barks and twigs are noticed on the tea bushes.

Plants have the ability to endure stress to a certain limit and try to overcome the unfavourable conditions by developing defence machanisms. Plants may suffer either from excessive soil moisture i.e. waterlogging or moisture deficit which is popularly known as **drought**. The districts of Cachar, Nowgong, Golaghat, part of North Bank, Dooars, Terai and parts of Darjeeling are identified as the drought prone areas in N.E. India.

DROUGHT AND ITS EFFECT ON CROP PRODUCTIVITY

Drought affects morphology, anatomy and physiology of plants. Physiological, biochemical and anatomical damages, however, occur much earlier than the visual symptoms of wilting. Wilting is a severe condition of soil moisture stress. It may be temporary or permanent in nature depending upon the available moisture in the soil.

Soil moisture is freely available for plant uptake around field capacity (i.e. 1/3rd bar suction). As the soil moisture deficit increases, water is held within the soil profile with greater tension, rendering it progressively unavailable to plant. At wilting point, the water is retained in the soil with such a great tension (i.e. 15 bar suction) that no moisture is available for plant uptake. The changes that are normally associated with moisture stress are :

Morphological : Leaf blade thickness, leaf area and new leaf formation are affected by drought. It suppresses the terminal and lateral bud growth and accelerates leaf shedding. The root has the tendency to go deeper and deeper in search of moisture. This phenomenon is just opposite to waterlogging.

Anatomical : Drought reduces the thickness of palisade and spongy parenchyma tissues of the leaves. Area and ratio of conducting tissues (xylem and phloem) are reduced in the leaf petioles, stems as well as in the roots. The root tissue is more affected than the stem tissue. By reducing the area of conducting tissues and by increasing the stomatal diffusion resistance, plants try to reduce the transpiration loss and overcome the adversity of drought.

Physiological : Carbondioxide assimilation is inhibited and partitioning of assimilates towards root system is greatly reduced, adversely affecting the carbohydrate reserve in the root system. Respiratory loss of assimilates also increases.

Biochemical : In drought affected plants the proline content of the leaves increases significantly. Water stress significantly increases the amount of total soluble sugars in leaf, stem and root. Drought affected plants contain reduced quantities of starch in the roots and more epicuticular wax in the leaves.

CHARACTERISTICS OF DROUGHT TOLERANT AND DROUGHT SUSCEPTIBLE CLONES

Stomatal Diffusion Resistance and Transpiration Rate

As and when the plants suffer from moisture deficit, the stomatal diffusion resistance increases trying to resist the water loss through transpiration. Drought tolerant clones have higher stomatal diffusion

resistance compared to drought susceptible clones. Consequently, the former category loses less water than the latter through transpiration during the period of drought. The cytokinin decreases in quantity in stressed bushes and is found to stimulate transpiration. TV clones like TV1, TV17, TV18 and TV20 have been found to have higher stomatal diffusion resistance and hence lesser transpiration rate than TV2, TV3, TV5 and TV15.

Relative Turgidity and Water Saturation Deficit

These two are the useful parameters for characterization of drought tolerance and susceptibility of clones. Drought tolerant clones have higher relative turgidity and lower saturation deficit compared to susceptible clones. TV clones like TV1, TV17, TV18 and TV20 have been found to have higher relative turgidity and hence lower water saturation deficit than TV3, TV4, TV13 and TV15.

Shoot and Leaf Water Potential

High leaf and shoot water potential during the moisture deficit period is a characteristic of drought tolerant clones. Tolerant clones like TV1, TV16, TV17 and TV18 were found to consistently exhibit higher water potential compared to susceptible ones like TV2, TV3, TV4 and TV6. Hence, drought tolerant clones have in-built capability to retain higher water content than the susceptible ones.

Normally clones of China origin exhibited higher shoot water potential than Cambod, whereas those of Assam origin showed the lowest shoot water potential. Due to high heterogeneity, seed stocks also show higher shoot water potential. Tea being a mesophyte will not be able to grow normally beyond -20 bars. In fact for good growth and production 25% to 100% plant available moisture has been found to be the requirement for tea bushes.

Table 1. Varietal differences in shoot water potential.

Varieties	Shoot water potential (- bars)
China	6.09
Cambod	7.23
Assam	8.21
Seed Stock	6.47

Proline and Epicuticular Wax Content

Higher quantities of proline and epicuticular wax content in the leaves are found in the drought tolerant clones than in the susceptible ones.

Table 2. Proline and epicuticular wax content in drought tolerant and susceptible clones.

Category	Clone	Proline ($\mu g/g$)	Wax ($\mu g/cm^2$)
Drought Tolerant	TV1	316.66	119.78
	TV17	320.83	132.70
	Mean	318.75	126.24
Drought susceptible	TV3	268.83	95.20
	TV13	296.67	105.87
	Mean	282.75	100.54
LSD at $P < 0.05$:	Clone	24.21	10.15
	Category	20.75	18.25

DROUGHT MANAGEMENT AND CROP GROWTH

When there is moisture stress in the soil and the air is dry, the continuous loss of water through evapotranspiration results in a setback of temporary or permanent nature. The rate of evapotranspiration is decided by many factors like the amount of foliage on the bush, ambient temperature, relative humidity, light intensity, wind velocity etc. The damaging effects of drought are generally observed to be more under the following conditions.

1. Young tea in initial 2-3 years.
2. Teas grown in light textured soils with low moisture holding capacity.
3. Waterlogged areas where the root development is highly restricted.
4. Unshaded tea areas.
5. Unpruned areas with thin top hamper and scanty maintenance foliage.
6. Light leaf Assam jats with flat leaf pose and large leaf area.

Drought suspends growth and it may even lead to permanent wilting and death in severe conditions. Some of the measures which help to reduce the adversity of drought are described below.

Short Term Measures

1. **Pruning** : Damaging effect of drought is less in pruned, deep skiffed and medium skiffed tea compared to light skiffed and unpruned tea. The reason behind is that by pruning the transpiring area of the plant is reduced and the pruning litter provides a thick mulch and thereby they suffer less. All pruning operations should be completed before the bushes start showing symptoms of drought i.e. pruning should be done before drought. Once severe stress is induced, defoliation or pruning has no value. Instead, the chances of die-back are further increased and the bushes are weakened.

2. **Leaf rise** : It has been seen that unpruned bushes with adequate maintenance foliage suffered less damage during drought compared to those given light or level-off skiff on thin top hamper. It is, therefore, required to examine the bushes in early September to ensure that they have sufficient healthy maintenance foliage. If not, a new layer of foliage by raising the plucking table is helpful. Raising by a leaf in time results in a new layer of dark green mature foliage with a terminal banji bud by January/February i.e. during the most dry period. Such foliage has a lower demand for water for sustaining it at a turgid condition.

3. **Cultivation and weed control** : Any form of soil stirring increases loss of moisture. Operations like hoeing and cheeling during drought are better avoided. If the operations are unavoidable, these should be completed before November so that there is no weed to compete with tea for moisture during the dry period. Deep rooted weeds should be uprooted manually.

4. **Mulching** : Mulching has tremendous benefit on the growth and productivity of tea. Besides soil moisture preservation, it increases the organic matter content and microbial activities in the soil. Mulching should be done during September to November. In autumn planting it should be done immediately after planting.

5. **Others** : Foliar application of potassium (K_2O) at the rate of 1 per cent increases shoot water potential, relative turgidity and finally maintains the favourable plant water status. Stomatal opening is controlled by potash application during the period of soil moisture deficit.

   Antitranspirants like Rallidhan at 1000 ppm and Antistress at 300 ppm increase the stomatal diffusion resistance, water potential as well as relative turgidity and simultaneously reduce transpiration. Antitranspirants restrict the gaseous exchange and, therefore, should be used when survival is more important than growth.

   Starch grafted polymers and acrylate now available in the market can also be tried to preserve and enhance soil moisture availability. When applied to soil before onset of drought, they absorb and

preserve moisture which is released slowly as and when a gradient is formed between the soil particles and polymers. These products are more beneficial for young tea and should be mixed with the excavated soil

Long Term Measures

1. **Shade :** Uniform shade is very much essential in tea more particularly in drought prone areas. Shade improves the productivity and protects the plants from radiation damage. It reduces leaf temperature by reducing the light intensity. Under shade the stomatal diffusion resistance is more and hence lesser transpiration. Average photosynthetic rate is also more under shade compared to no shade condition. It also reduces moisture evaporation from the soil. Thus shade has physical and physiological importance in reducing intensity of drought and enhancing crop growth.

2. **Drainage :** Waterlogging during monsoon causes poor root development. Such plants suffer more from drought during winter. Proper drainage encourages root growth and helps the plants to withstand drought to a great extent.

3. **Irrigation :** Replenishment of soil water deficit through artificial means is irrigation. Irrigation should be taken up as and when the soil moisture deficit falls below 50 per cent of the field capacity. Under droughty conditions irrigation at shorter interval with lesser quantity of water is beneficial compared to high quantity at longer interval

4. **Planting materials :** Light leaf Assam jats or clones are generally not suitable materials for planting in extremely drought prone areas without any facility for irrigation. Most of the seed stocks and clones developed at Tocklai have, however, tolerance for drought and, therefore, will perform well under good field management practices. The seed stocks and clones that are comparatively more tolerent to drought are listed below. It may be stated that a good shade standard and appropriate pruning policy help the plants to recover drought effects faster than under conditions of poor shade and unprune in longer pruning cycle.

   Clones - TV17, TV22, TV23, TV30; Seed Stocks - TS462, TS463, TS464 and TS 449

   An integrated approach combining both short and long term measures cited above can only help to minimise the adverse effects of drought.

WEED CONTROL IN TEA—CHOICE OF WEEDICIDE AND EFFECIENT WEED CONTROL SCHEDULES

J. Chakravartee, M. P. Sinha and A. C. Barbora

Weed competition in tea plantations may cause crop loss to the extent of 10-15 per cent and may remove upto 252 kg of soil nitrogen per hectare annually in young tea. Their control is implicit considering the phenomenal enhancement in yield by reducing the stress on moisture, nutrients and space. Weed control in tea using herbicides has been found to be advantageous with a cost-benefit ratio of 1:10 or more. Out of 5,600 metric tonnes of herbicides applied annually in our country, about 112 metric tonnes are used in tea plantations alone.

CRITICAL PERIOD OF WEED COMPETITION

Field experiments conducted at Borbhetta have revealed that the critical period of weed competition in tea is from April to September and hence control during this period is essential. If weed control is started later than April and a clean ground is not achieved by the month of June, it will result in substantial weed competition and adverse effect on the growth and yield of tea. Controlling weeds manually has become increasingly expensive and there is often a shortage of labour during the peak season. To cope with the problem, herbicides were introduced in tea industry almost three decades ago with excellent results.

With the increasing consumption of herbicides, there is also a need to use them judiciously and economically. For efficient and cost-effective results, the important aspects which need to be considered are :

1. Monitoring the changes occurring in weed spectrum.
2. Adopting herbicide programmes appropriate to the weed flora.
3. Improving the herbicide-spray efficiency.

CHOICE OF HERBICIDES

At present only seven herbicides are recommended for use in the tea plantations of North East India. Their names, tested brands and action specificity are given in Table 1.

Table 1. Recommended herbicides, tested brands and specificity of action.

Herbicide	Tested brand	Mode of action	Specificity
1. 2, 4-D Sodium salt	Taficide 80, Kar-D, 2, 4-D Sodium salt (suvochem, Herbicide India) Fernoxone	Mainly post-emergence, systemic-readily translocated	Mainly used as broad leaf killer
2. Paraquat	Gramoxone, Paralac	Post-emergence, mainly contact with some translocation	Broad spectrum
3. Dalapon		Post-emergence, translocated	Specific to grassy weeds
4. Glyphosate	Round-up, Glycel, Glyphotaf 41S, Glyphosate 41 WSC (Herbicide India)	Post-emergence, translocated	Mainly used as grass killer
5. Simazine	Tafazine 50 W	Pre-emergence, translocated	Broad spectrum
6. Diuron	Klass (Hoechst)	Pre-emergence, translocated	Broad spectrum
7. Oxyfluorfen	Goal	Pre-emergence, contact	Broad spectrum

Simazine, Diuron and Oxyfluorfen are pre-emergent herbicides and safe for tea at recommended doses. Herbicides like 2,4-D, Dalapon and Glyphosate are post-emergent recommended for selective use. Paraquat is a contact, broad spectrum post-emergent herbicide. Glufosinate ammonium, a new herbicide has shown promise in tests conducted at Tocklai and is ready for certification and recommendation to the industry. This is a broad spectrum contact herbicide which controls a large number of obnoxious weeds. For best results certain conditions are necessary for the herbicides to work effectively. These are :

Pre-emergent herbicides

1. Apply on moist and clean ground.
2. Use Diuron in tea above 3 years of age.
3. Do not disturb the soil after application or do not apply on disturbed soils.
4. Avoid use in sandy soils.

Post-emergent herbicides

1. Apply on active growth stage.
2. Sickle tall weeds and apply on regrowth.
3. Paraquat in young tea should be used with care.
4. Dalapon should not be used in tea below 3 years of age.

RATES OF APPLICATION OF HERBICIDES

The optimum rates of application for different herbicides used in tea are given in Table 2. These are expressed in the form of dilution (amount of formulated herbicide in 200 litres of water) and per cent concentration of the product in spray solution. However, in nursery only Simazine @ 5 gram in 1.0 litre of water or Oxyfluorfen @ 2.5 ml per litre of water should be used. In young tea of 0-3 years Simazine should be used at 1.00 to 1.25 kg only in 200 litres of water to avoid any phytotoxicity.

Table 2. The rates of application of various herbicides recommended for use in young and mature tea.

Herbicide	Dilution (amount of herbicide per 200 l of water)	Concentration (%)
1. 2,4-D		
Sodium salt	500 g	0.25
Dimethylamine salt	250 - 400 ml	0.12 - 0.20
2. Paraquat		
First round	670 ml	0.33
Subsequent rounds	500 ml	0.25
3. Dalapon (Tea over 3 yrs only)	1.75 kg	0.87
4. Glyphosate		
On Polygonum, Arundinella,		
Saccharum	1.5 lts	0.75
On other perennials	1.0 lt	0.50
5. Simazine	1.50 - 2.0 kg	0.75 - 1.00
6. Diuron alone or as tank mix with paraquat (Tea over 3 years only)	0.4 kg	0.20
7. Oxyfluorfen	0.5 lt	0.25

HERBICIDAL COCKTAILS

An economic and effective weed control programme is possible by selecting the right herbicide for a particular weed flora. Sometimes depending on magnitude of weed intensity and stage of growth suitable mixtures are also applied. A broad guideline is given in Table 3.

Table 3. Use of herbicides and weed flora.

Type of weed flora	Young tea	Mature tea
Predominantly grassy	Oxyfluorfen+Glyphosate or Glyphosate alone	Paraquat, or Paraquat+Diuron, or Paraquat+Simazine
Predominantly broad leaf	2,4-D with care	2,4-D
Mixed weeds	Glyphosate+2,4-D	Paraquat+2,4-D
Thatchy	Glyphosate	*Dalapon or Glyphosate
Thatch and broadleaf	Glyphosate+2,4-D	Dalapon+2,4-D

* Dalapon followed by Paraquat

Paraquat + Diuron : Paraquat can be mixed with pre-emergence Diuron for more effective and long duration control of some of the grasses and broad leaf weeds. This cocktail should be used over fresh growth. The cocktail should not, however, be used in tea under 3 years of age.

Paraquat + 2,4-D : Paraquat is effective on grasses and a few annual broad leaf weeds but gives only partial control of Bagrakote. Bagrakote and most of the broadleaf annuals are controlled well by 2,4-D. Hence, in a mixed weed spectrum covering 50 per cent or lesser area under broad leaf weeds with Bagrakote as the major component, this cocktail is found to be effective and economical. The rates of application for two herbicides will remain the same as applied individually.

Paraquat + Simazine : This mixture acts in the similar way as Paraquat+Diuron.

Dalapon + 2,4-D : In this mixture Dalapon controls perennial grasses, particularly *Imperata* (thatch grass) and 2,4-D eliminates broad leaf weeds.

Glyphosate + 2,4-D : Ferns can be controlled effectively by reducing the recommended dose of Glyphosate from 3 litres/ha to 1.6 litre/ha with addition of 0.8 kg of 2,4-D as tank mix.

Glyphosate + Oxyfluorfen : Satisfactory control of grasses could also be achieved by reducing the dependence on Glyphosate from the recommended dose of 1 l/200 l to 0.625 l/200 l with the addition of 0.3 kg Oxyfluorfen as tank mix.

GLYPHOSATE

Glyphosate can be used in young tea as well as in mature tea as a broad spectrum post-emergence translocated herbicide. Rate of application for various weeds is given in Table 4. It should be applied when the target weeds are in active growth stage. Unlined steel or galvanised containers SHOULD NOT be used for preparation of Glyphosate solution.

Table 4. Rates or concentrations of Glyphosate for control of some of the obnoxious weeds in tea.

Weed species controlled by 2 l/ha at 1:200 dilution (0.50% concentration)	Weed species controlled by 3 l/ha at 1.5/200 dilution (0.75% concentration)
Axonopus compressus	*Arundinella bengalensis*
Cynodon dactylon	*Polygonum chinense*
Digitaria sanguinalis	*Saccharum spontaneum*
Imperata cylindrica	
Paspalum scrobiculatum	
Polygonum perfoliatum	
Setaria palmifolia	

SPRAYING OF HERBICIDES

Spray volume : The quantity of spray solution required would depend on (a) type of herbicide used (contact or translocated), (b) intensity of weed infestation, (c) stage of weed growth and (d) weed control efficiency in the previous year. The spray volumes required to cover uniform weed infestation of one hectare of different types of herbicides used in tea are given in Table 5.

Table 5. Spray volumes for different herbicides to cover uniform weed infestation of one hectare

Type of herbicide	Mode of action	Herbicide(s)	Spray vol. (l/ha)
Contact	Post-emergence	Paraquat	450-500
Contact + Translocated	Post-emergence	a. Paraquat + Diuron	450-500
		b. Paraquat + Simazine	450-500
		c. Paraquat + 2,4-D	450-500
Translocated	Post-emergence	2,4-D, Dalapon, Glyphosate	350-400
Translocated	Pre-emergence	Diuron,Simazine, Oxyfluorfen	400-500

Spray adjuvant : Efficiency of translocated herbicides can be enhanced by the addition of wetting agents, sticking agents and fertilizers to the spray solution. Wetting agent like Teepol reduces surface tension between the spray drops and the leaf surface. The wetting (Teepol) or sticking (Triton AE) agents are used either single or in combination at 0.06 per cent (120 ml in 200 l). Sticking agents are not effective if it rains within two hours of spraying. Ammonium sulphate or Urea should be mixed at 0.5 per cent (1.0 kg in 200 l) in 2,4-D solution while only ammonium sulphate at 0.5 per cent (1.0 kg in 200 l) is suggested with Glyphosate.

Sprayers and nozzles : Herbicide spraying should be done by using hand operated Knapsack sprayer fitted with a floodjet fan type nozzle; when weed infestation is intense and uniform, WFN 40 nozzle should be used. However, sparse weed infestation would require WFN 24 nozzle for spot application. The spray delivery pressure should be maintained around 10 to 15 psi (700 to 1050 g/cm^2) for optimum discharge and to avoid wastage. The nozzle should be used only for about 200 spraying hours and must be changed by experience when it appears to discharge more spray solution than its original discharge. Stainless steel nozzles may have much longer life than the brass nozzles.

The spray delivery height from the ground should be 9 to 12 inches (22.5 to 30 cm). Spraying during rains as well as high wind should be avoided. Normally one hand operated sprayer is required for every 6 to 8 hectares (15 to 20 acres) of tea area and

accordingly as per the size of the garden, required number of sprayers should be acquired in advance. Protective hoods should be used while spraying young tea areas for preventing drift damage.

HERBICIDE TOXICITY

Herbicides approved by Tocklai are quite safe to tea if applied as per recommendation. Herbicide toxicity on tea may occur due to the following factors:

1. Application of herbicides at rates higher than the recommended optimum.

2. Nondirected spraying.

3. Spray drift.

4. Leaching of soil-applied herbicides by heavy rains.

5. Age of tea.

Specific toxicity symptoms of herbicides on tea are explained in Table 6.

Table 6. Specific toxicity symptoms of herbicides.

Herbicide	Toxicity symptoms	Precautions
Diuron	Leaf chlorosis including veins starting from the centre of the leaf towards the margin.	There should be a rain free period after application. Autumn application is better.
Simazine	Leaf chlorosis starting from the margin towards mid rib. In contrast to diuron toxicity the mid rib and veins remain green. Leaves curl upwards.	-do-
Dalapon	Leaf chlorosis and necrosis in younger leaf start from margin towards mid rib.	Directional spray in wind free period.
Paraquat	Wilting of leaf followed by drying and defoliation.	-do-
2,4-D	Young leaves show typical curling, twisting, rolling and yellowing symptoms.	-do-
Glyphosate	Defoliation of leaves. Appearance of small multiple shoots similar to boron deficiency.	Use shield. Apply one round of Zinc sulphate + Borax @ 0.25% each.

WEED SURVEY AND HERBICIDE PROGRAMMES

Weed flora and the intensity of weed infestation may vary from area to area within an estate. Before deciding the kind of herbicide to be used, it is useful that most predominant weed species and percentages of their occurrence in each section are recorded. The information thus obtained from the survey should be used to prepare a herbicide schedule for each section. The weed survey should be done again after application of herbicide so that the changes in weed situations can be monitored. Memorandum No. 29 may be referred for identification of the predominant weed species.

Herbicide programmes vary with weed situations. A particular programme may be used as long as the relevant weed situation exists. But the weed spectrum changes over the years and then suitable programmes for the new weed situations should be used.

AUTUMN APPLICATION OF PRE-EMERGENT HERBICIDE

Weed infestation (broad leaf weeds and grasses) in the years following light pruning, deep skiffing and medium pruning often becomes severe due to exposure of the soil. The application of pre-emergent herbicides in the normal spraying season (March-April) becomes difficult because the pruning litter covers the ground and prevents the herbicide spray from reaching the soil uniformly.

This problem can be overcome by applying pre-emergent herbicides in autumn, preferably from October to any time before pruning and skiffing. The herbicide remains active till next June/July. This shifting in time of application to the previous autumn helps in relieving labour shortage in spring. Better weed control efficacy and longer duration of activity can be obtained with Diuron at 1-2 kg a.i./ha.

COSTING

A rough cost estimate of chemical weed control in young and mature teas under varying conditions is given in Appendix.

RESIDUE HAZARDS

All the seven herbicides currently in use in N.E. India are potentially hazardous. Uptake of chemicals by tea should be minimised by their judicious use along with cultural and other methods that help minimising the need of repeated use of chemicals.

APPENDIX

MODEL WEED CONTROL SCHEDULES (Estimate for one hectare)

1. Young tea areas

Spray round	Time of application	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
1.1 With pre-emergent herbicide										
1st	April	Oxyfluorfen or Simazine or Oxyfluorfen + Glyphosate	1.5 l 3 kg 0.45 l + 1.875 l	600 (B)	4	1848.00 828.00 554.40 +678.75	140.00	Chem Wages	\1494.75 280.00	2582.25
2nd	June	Glyphosate or Glyphosate + 2,4-D	1.5 l 1.5 l + 0.75 kg	300 (S)	2	543.00 543.00 +67.50	70.00	Overhead charge	84.00	
3rd	Sep-Oct	Paraquat	0.75 l	300 (S)	2	123.75	70.00	Depr. of sprayer	60.00	
								Total	**1918.75**	**3006.25**
1.2 Without pre-emergent herbicide										
1st	Mar-Apr	Glyphosate	3 l	600 (B)	4	1086.00	140.00	Chem Wages	1820.25 350.00	
2nd	May	2,4-D	0.75 kg	300 (S)	2	67.50	70.00	Overhead charge	105.00	
3rd	June	Glyphosate	1.5 l	300 (S)	2	543.00	70.00	Depr. of sprayer	60.00	
4th	Sept-Oct	Paraquat	0.75 kg	300 (S)	2	123.75	70.00			
								Total	**2335.25**	

** **B = Blanket application**
** **S = Spot application**
** **Depr. = Depreciation**

** **Wages included an overhead charge @ 30% on total wages**
** **Depreciation of sprayer is taken as Rs. 60.00/ha**

Min. = Minimum cost
Max. = Maximum cost

2. Medium and light pruned areas (with infills)

Weed flora - Mixed stand of weeds

Spray round	Time of application	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
1st	April	Oxyfluorfen or Simazine	1.25 l 3.75 kg	500 (B)	3.5	1540.00 1035.00	122.50	Chem Wages	1645.50 262.50	2274.25
2nd	June	Glyphosate	1.5 l	300 (S)	2	543.00	70.00	Overhead charge	79.00	
3rd	Sept-Oct	Paraquat or 2,4-D or a mixture	750 ml 750 g 750ml+750 g	300 (S)	2	123.75 67.50 191.25	70.00	Depr. of sprayer	60.00	
								Total	**2047.00**	**2675.75**

3. Medium, light pruned and deep skiffed areas
Weed flora - Mixed stand of weeds

Spray round	Time of application	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
3.1 With pre-emergent herbicide										
1st	April	Paraquat + Diuron	1.25 l 1.00 kg	500 (B)	3.5	206.25 565.00	122.50	Chem Wages	906.25 262.50	962.50
2nd	June	Paraquat or 2,4-D	750 ml 750 g	300 (S)	2	123.75 67.50	70.00	Overhead charge	78.75	
3rd	Sept-Oct	2,4-D	750 g	300 (S)	2	67.50	70.00	Depr. of sprayer	60.00	
								Total	**1307.50**	**1363.75**
3.2 Without pre-emergent herbicide										
1st	April	Paraquat + 2,4-D	1.25 l 1.25 kg	500 (B)	3.5	206.25 112.50	122.50	Chem Wages	592.50 315.00	648.75
2nd	June	Paraquat	1.25 l	500 (B)	3.5	206.25	122.50	Overhead charge	94.50	
3rd	Sept-Oct	2,4-D or Paraquat	0.75 kg 0.75 l	300 (S)	2	67.50 123.75	70.00	Depr. of sprayer	60.00	
								Total	**1062.00**	**1118.25**

4. **Medium, light pruned and deep skiffed teas** (without infills)

Weed flora - Predominantly broad leaf weeds

Spray round	Time of application	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
4.1 With pre-emergent herbicide in spring										
1st	April	Diuron + 2,4-D or Diuron + Paraquat	1.00 kg 1.25 kg 1.00 kg 1.25 l	500 (B)	3.5	565.00 112.50 565.00 206.25	122.50	Chem Wages	868.75 262.50	1086.25
2nd	June	Paraquat or 2,4-D or a mixture	0.75 l 0.75 kg 0.75l+0.75 kg	300 (S)	2	123.75 67.50 191.25	70.00	Overhead charge	78.75	
3rd	Sept-Oct	Paraquat	0.75 l	300 (S)	2	123.75	70.00	Depr. of sprayer	60.00	
								Total	**1270.00**	**1487.50**
4.2 With pre-emergent herbicide in autumn										
1st	Sept-Oct (Before pruning)	Diuron	1.00 kg	500 (B)	3.5	565.00	122.50	Chem Wages	823.75 332.50	947.50
2nd	April	2,4-D	0.75 kg	300 (S)	2	67.50	70.00	Overhead charge	99.75	
3rd	June	Paraquat or 2,4-D or a mixture	0.75 l 0.75 kg 750ml+750 g	300 (S)	2	123.75 67.50 191.25	70.00	Depr. of sprayer tank etc	60.00	
4th	Sept-Oct	Paraquat	0.75 l	300 (S)	2	123.75	70.00			
								Total	**1316.00**	**1439.50**

4.3 Without pre-emergent herbicide

Spray round	Time of applica-tion	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
1st	April	Paraquat or 2,4-D or a mixture	1.25 l 1.25 kg 1.251+1.25 kg	500 (B)	3.5	206.25 112.50 318.75	122.50 122.50	Chem Wages Overhead charge	416.25 385.00 115.50	746.25
2nd	June	2,4-D	1.25 kg	500 (B)	3.5	112.50				
3rd	Jul-Aug	Paraquat	0.75 l	300 (S)	2	123.75	70.00	Depr. of sprayer	60.00	
4th	Sept-Oct	Paraquat or 2,4-D or a mixture	0.75 l 0.75 kg 750 ml+750 g	300 (S)	2	123.75 67.50 191.25				
								Total	**976.75**	**1306.75**

5. Light pruned and deep skiffed areas

Weed flora - predominantly grassy weed

5.1 Pre-emergent herbicide in spring application

Spray round	Time of applica-tion	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
1st	April	Diuron + Paraquat	1.00 kg 1.25 l	500 (B)	3.5	565.00 206.25	122.50	Chem Wages	962.50 262.50	1086.25
2nd	June	Paraquat or 2,4-D or a mixture	0.75 l 0.75 kg 0.751+0.75 kg	300 (S)	2	123.75 67.50 191.25	70.00	Overhead charge	78.75	
3rd	Sept-Oct	Paraquat	0.75 l	300 (S)	2	123.75	70.00	Depr. of sprayer	60.00	
								Total	**1363.75**	**1487.50**

5.2 **Pre-emergent herbicide in autumn application**

Spray round	Time of application	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
1st	Sept-Oct (Before pruning)	Diuron + Paraquat	1.00 kg 1.25 l	500 (B)	3.5	565.00 206.25	122.50	Chem Wages	1075.00 385.00	1281.25
2nd	April	Paraquat	0.75 l	300 (S)	2	123.75	70.00	Overhead charge	115.50	
3rd	June	Paraquat or 2,4-D or a mixture	1.25 l 1.25 kg 1.25l+1.25 kg	500 (B)	3.5	206.25 112.50 318.75	122.50	Depr. of sprayer	60.00	
4th	Sept-Oct	2,4-D	0.75 kg	300 (S)	2	67.50	70.00			
								Total	**1635.50**	**1841.75**
5.3 Without Pre-emergent herbicide										
1st	April	Glyphosate	2.50 l	500 (B)	3.5	905.00	122.50	Chem Wages	1220.00 262.50	
2nd	June	Paraquat + 2,4-D	0.75 l 0.75 kg	300 (S)	2	123.75 67.50	70.00	Overhead charge	78.75	
3rd	Sept-Oct	Paraquat	0.75 l	300 (S)	2	123.75	70.00	Depr. of sprayer	60.00	
								Total	**1621.25**	

6. **Unpruned and medium skiffed teas**

Weed flora : Mixed stand of weeds

Spray round	Time of application	Chemical used	Qty/ha	Spray volume l/ha	Mandays per ha	Cost of chemical per ha (Rs)	Wages @ Rs.35/day (Rs)		Total cost per ha (Rs) Min.	Max.
6.1 With low vacancy										
1st	April	Paraquat + 2,4-D	1.25 l 1.25 kg	500 (B)	3.5	206.25 112.50	122.50	Chem Wages	592.50 262.50	648.75
2nd	June	Paraquat	1.25 l	500 (B)	2	206.25	70.00	Overhead charge	78.75	
3rd	Sept-Oct	2,4-D or Paraquat or Autumn application of pre-emergent herbicide	0.75 kg 0.75 l	300 (S)	2	67.50 123.75	70.00	Depr. of sprayer	60.00	
								Total	**993.75**	**1050.00**
6.2 With high vacancy										
1st	April	Glyphosate + 2,4-D	2.50 l 1.25 kg	500 (B)	3.5	905.00 112.50	122.50	Chem Wages	1208.75 262.50	1265.00
2nd	June	Paraquat	0.75 l	300 (S)	2	123.75	70.00	Overhead charge	78.75	
3rd	Sept-Oct	2,4-D or Paraquat	0.75 kg 0.75 l	300 (S)	2	67.50 123.75	70.00	Depr. of sprayer	60.00	
								Total	**1610.00**	**1666.25**

The cost of chemicals has been calculated on the basis of existing price rate as given below :

1. Diuron	Rs 638.50/kg
2. Simazine	Rs. 275.00/kg
3. Oxyfluorfen	Rs. 1597.00/litre
4. Glyphosate	Rs. 378.00/litre
5. 2,4-D	
a) Sodium salt	Rs. 140.00/kg
b) Amine salt	Rs. 252.00/kg
6. Paraquat	Rs. 227.00/litre

MANAGEMENT OF TEA PESTS

J. Chakravartee and Karan Singh

Tea is a perennial plantation crop and provides a favourable breeding ground for a variety of pests (Table 1). Figure 1 shows the distribution of various pests in different parts of tea plant. During the last few decades, use of pesticides has been playing a major role in reducing the crop loss due to pest attack. But their application invariably leaves toxic residues in the crop though the toxicity differs from one pesticide to another. Too much dependence on chemical pesticides and their indiscriminate use even during a critical pest situation may lead to high deposition of residues in made tea exceeding the permissible limits.

Tea is the most scientifically monitored agrobased commodity as compared to other agricultural crops. A sizable amount of tea is also exported to various global destinations. To popularize it as health or habitual drink, the use of pesticides has to be rationalized and all producers must become conscious about the possible hazards of agro-chemicals either to the environment or to the human health. Various international agencies like EPA, Codex, EEC, FAO/WHO, Food Sanitation Law, Japan, Medico Biological Standards and USSR have fixed the Maximum Residue Limits (MRL) on a group of pesticides in tea (Table 2). It is, therefore, necessary to select the right chemical, apply at a right dose, at a right time and on the right target. It is also important to note that safer pesticides should be taken as one of the tools for the management of pests and diseases which need to be integrated with other means of control such as cultural, mechanical, physical and biological control. The pre-harvest intervals (PHIs) should be so adjusted at different times in the year to eliminate/minimize pesticide residues in tea.

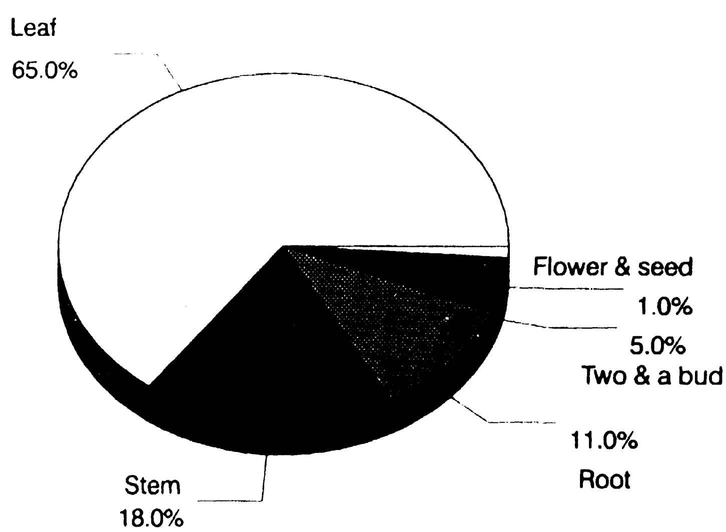


Fig. 1. Per cent distribution of pests on different parts of tea plants

Table 1. Tea pests with the sites of attack and their times of occurrence.

Pests	Site of attack(s)	Time of occurrence(s)
A. Chewing pests		
1. Early instar bunch caterpillar	Lower epidermis of leaves	Moths : Mar-Apr/May-Jun/Jul-Aug/Oct-Nov Caterpillars : Mar-Apr/May-Jun/Jul-Aug/Oct-Nov Chrysalids : Apr-May/Jun-Jul/Aug-Sep/Nov-Dec
Late instar bunch caterpillar	Whole leaf	
2. Red slug caterpillar	Under surface of mature leaves/ bark of stem	Moths : Jan-Mar/May-Jun/Jul-Aug/Sep-Oct Caterpillars : Feb-Apr/Jun-Jul/Aug-Sep/Oct-Jan Chrysalids : Mar-May/Jul-Aug/Sep-Oct/Nov-Feb
3. Early instar looper	Young leaves	Moths : Feb-Mar/May/Jul/Aug-Oct Caterpillars : Mar-Apr/May-Jun/Jul-Aug/Sep-Oct Chrysalids : Apr-May/Jul-Aug/Aug-Sep/Oct-Nov
Late instar looper	Mature leaves/entire foliage	
4. Psychid caterpillar	Mature leaves/bark	May-Jun/Sep-Dec
5. Nettle grub	Lower surface of mature leaves	Apr-Sep
6. Flush worm	Bud	Jan-May
B. Sucking pests		
7. Helopeltis	Young leaves/buds/tender stems	Feb-Nov
8. Jassid	Young leaves/tender stems	Feb-Jul
9. Aphids	Buds/tender stems/young leaves	Jan-Apr
10. Thrips	Unopened/partly opened buds/ young leaves	Jan-Jul
11. Scale insects	Leaves/stems	Jan-Jul
12. Stem mealy bugs	Stems	Jan-Jul
13. Root mealy bugs	Roots	Jan-Jul
14. Red spider mite	Upper surface of mature leaves	Jan-May/Sep-Oct
15. Scarlet mite	Lower surface of mature leaves/ young stems	Feb-Jun/Oct-Nov
16. Pink mite	Lower surface of young leaves	Mar-Jun/Oct-Nov
17. Purple mite	Upper surface of older leaves	Feb-Apr/Oct-Nov
C. Stem borer and soil borne pests		
18. Red stem borer	1-2 year old stem	Moths : Mar-Apr/Aug-Oct
19. Cockchafer	Bark of stem just below soil surface/roots	Apr-Jun
20. Cricket	Tender stem of young seedlings	Mar-Oct
21. Termite	Stems/root	Dec-Feb/Apr-Jun/Aug-Oct
22. Bark eating borer	Stem	Moths : Apr-May
23. Cerambycid borer	Stem/root	Mar-Apr/Sep-Oct

Table 2. Maximum residue limits of some pesticides.

Pesticide	Maximum tolerance limit (in ppm)					
	EPA USA	CODEX UK	GERMAN/ EEC	FAO/ WHO	JAPAN	USSR
Dicofol	45	8	-	5	-	-
Ethion	10	5	2	7	-	-
Endosulfan	24	30	30	30	-	-
Phosalone	8	-	-	-	-	-
Deltamethrin	-	10	5	10	10	-
Cypermethrin	-	20	-	20	20	-
Permethrin	-	-	-	20	20	-
Chlorpyriphos	-	-	-	-	3	-
Formothion	-	-	-	-	-	0.2
Fenitrothion	-	-	-	0.5	-	-
Dimethoate	-	-	0.2	-	-	-
Cartap	-	-	20	-	-	-
Diflubenzuron	-	-	-	-	20	-

PESTICIDE CONSUMPTION IN TEA

A survey conducted in N.E. Indian tea estates has indicated that the quantum of pesticides used in tea is not very high (Table 3) but their irrational use could lead to high residues in made tea.

Table 3. Pesticide consumption (kg/l/ha) pattern in different regions of N. E. India in 1991.

Pesticide	Region				
	Upper Assam	North Bank	Cachar	Dooars & Terai	Darjeeling
Acaricide	2.96	2.43	2.48	3.38	1.29
Insecticide	3.04	3.32	3.61	5.35	1.90
Fungicide	1.67	1.25	N.A.	0.19	1.28
Herbicide	3.97	4.02	4.82	8.05	3.73
Total	11.64	11.02	10.91	16.97	8.20

Use of pesticides in flushing and non-flushing periods of tea is a critical factor that determines the residue levels in the finished product.

Many synthetic organic insecticides and acaricides have been currently utilized for controlling major and minor pests of tea. Recommendation of insecticides is a dynamic process in which approval of new ones and withdrawal of old ones take place after proper testing and evaluation. The pesticides currently recommended for use in tea in the N.E. India are listed below :

1. **During flushing period : (Mid Feb - Nov)**

Pesticides	**Remarks**
Endosulfan	
Phosalone	**Moderately degradable**
Dicofol	**Spot treatment**
Ethion	**Spot treatment**
Sulphur	
Copper oxychloride	
Synthetic pyrethroid	
Cypermethrin	**Fast degradable**
Fenvalerate	**Fast degradable**
Fluvalinate	**Fast degradable**
Deltamethrin	**Fast degradable**

2. During non-flushing period (Dec - mid Feb)

Pesticides	Remarks
Thiometon	
Malathion	Moderately degradable
Monocrotophos	
Dimethoate	Moderately degradable
Fenitrothion	Moderately degradable
Chlorpyriphos	
Quinalphos	Moderately degradable
Phosphamidon	
Formothion	
Acephate	

Out of these chemicals some are relatively safer even for use during the plucking period. But the present regulation warrants establishment of MRLs in made tea before using in the flushing period. Tocklai Experimental Station (Tea Research Association) has already established a Pesticide Residue Laboratory and has been cntinuing studies on the estimation of residues of various pesticides at different time intervals, viz. 0,1,3,5,7,14,21 and 35 days after application of pesticides under different agro- climatic conditions which will help the industry to monitor their spraying schedule in order to eliminate residues in the finished tea. Various other R & D institutions in India have also been working in this direction.

RESIDUES IN MADE TEA

Residue studies conducted at Tocklai and elsewhere showed that most of the recommended pesticides leave little residues in the made tea if the suggested dose and interval between pesticidal treatment and harvest are followed properly. This is because after spraying the residues of the pesticides on the treated shoots decline with time. Various factors responsible for this decline are rainfall, dew, evaporation, photodegradation, biodegradation, growth and dilution, etc. Depending upon the thermal stability and vapour pressure, residues of some of the pesticides, may also be lost during manufacturing of tea. It has been reported that higher the vapour pressure the greater is the degradation during processing. Finally it is important to note that only a fraction of the residues in made tea may come to the hot water brew or liquor.

Generally only those pesticides which have high water solubility may potentially be transferred to the tea cup in significant amounts. Thus, while assigning MRL values on made tea, these factors are also taken into consideration. Nevertheless, the fact remains that all pesticides are toxic chemicals and one should ensure that their levels do not exceed the prescribed MRLs so that they are safe for consumption. In a recent survey, residues of ethion and Dicofol were detected in samples of both first and second flushes of Darjeeling tea. In some samples (28 -32%) the residues were above the MRLs. In fact tea exported from India frequently carried residues of ethion, Dicofol, quinalphos etc., and in some samples they exceeded the MRLs. In addition, residues of banned pesticides like DDT, BHC, aldrin, tetradifon, etc. were also detected in the past. This shows that some of the tea estates are still unconcerned about the hazards already stated. Residues of DDT, BHC, aldrin, etc. can persist for very long periods. One must realize that if the problem of pesticide residues in tea continues, it will be impossible to promote tea as a health drink, and thus jeopardising not only export of Indian tea but also hampering the domestic consumption. One way of minimising the excessive residue problem is total rationalization of the pesticide uses and studying the pests behaviour more thoroughly so that an effective integrated pest management approach becomes feasible.

Table 2. Maximum residue limits of some pesticides.

Pesticide	Maximum tolerance limit (in ppm)					
	EPA USA	CODEX UK	GERMAN/ EEC	FAO/ WHO	JAPAN	USSR
Dicofol	45	8	-	5	-	-
Ethion	10	5	2	7	-	-
Endosulfan	24	30	30	30	-	-
Phosalone	8	-	-	-	-	-
Deltamethrin	-	10	5	10	10	-
Cypermethrin	-	20	-	20	20	-
Permethrin	-	-	-	20	20	-
Chlorpyriphos	-	-	-	-	3	-
Formothion	-	-	-	-	-	0.2
Fenitrothion	-	-	-	0.5	-	-
Dimethoate	-	-	0.2	-	-	-
Cartap	-	-	20	-	-	-
Diflubenzuron	-	-	-	-	20	-

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Acaricide	2.96	2.43	2.48	3.38	1.29
Insecticide	3.04	3.32	3.61	5.35	1.90
Fungicide	1.67	1.25	N.A.	0.19	1.28
Herbicide	3.97	4.02	4.82	8.05	3.73
Total	11.64	11.02	10.91	16.97	8.20

Use of pesticides in flushing and non-flushing periods of tea is a critical factor that determines the residue levels in the finished product.

Many synthetic organic insecticides and acaricides have been currently utilized for controlling major and minor pests of tea. Recommendation of insecticides is a dynamic process in which approval of new ones and withdrawal of old ones take place after proper testing and evaluation. The pesticides currently recommended for use in tea in the N.E. India are listed below :

1. **During flushing period : (Mid Feb - Nov)**

Pesticides	**Remarks**
Endosulfan	
Phosalone	**Moderately degradable**
Dicofol	**Spot treatment**
Ethion	**Spot treatment**
Sulphur	
Copper oxychloride	
Synthetic pyrethroid	
Cypermethrin	**Fast degradable**
Fenvalerate	**Fast degradable**
Fluvalinate	**Fast degradable**
Deltamethrin	**Fast degradable**

2. During non-flushing period (Dec - mid Feb)

Pesticides	Remarks
Thiometon	
Malathion	Moderately degradable
Monocrotophos	
Dimethoate	Moderately degradable
Fenitrothion	Moderately degradable
Chlorpyriphos	
Quinalphos	Moderately degradable
Phosphamidon	
Formothion	
Acephate	

Out of these chemicals some are relatively safer even for use during the plucking period. But the present regulation warrants establishment of MRLs in made tea before using in the flushing period. Tocklai Experimental Station (Tea Research Association) has already established a Pesticide Residue Laboratory and has been cntinuing studies on the estimation of residues of various pesticides at different time intervals, viz. 0,1,3,5,7,14,21 and 35 days after application of pesticides under different agro- climatic conditions which will help the industry to monitor their spraying schedule in order to eliminate residues in the finished tea. Various other R & D institutions in India have also been working in this direction.

RESIDUES IN MADE TEA

Residue studics conducted at Tocklai and elsewhere showed that most of the recommended pesticides leave little residues in the made tea if the suggested dose and interval between pesticidal treatment and harvest are followed properly. This is because after spraying the residues of the pesticides on the treated shoots decline with time. Various factors responsible for this decline are rainfall, dew, evaporation, photodegradation, biodegradation, growth and dilution, etc. Depending upon the thermal stability and vapour pressure, residues of some of the pesticides, may also be lost during manufacturing of tea. It has been reported that higher the vapour pressure the greater is the degradation during processing. Finally it is important to note that only a fraction of the residues in made tea may come to the hot water brew or liquor.

Generally only those pesticides which have high water solubility may potentially be transferred to the tea cup in significant amounts. Thus, while assigning MRL values on made tea, these factors are also taken into consideration. Nevertheless, the fact remains that all pesticides are toxic chemicals and one should ensure that their levels do not exceed the prescribed MRLs so that they are safe for consumption. In a recent survey, residues of ethion and Dicofol were detected in samples of both first and second flushes of Darjeeling tea. In some samples (28 -32%) the residues were above the MRLs. In fact tea exported from India frequently carried residues of ethion, Dicofol, quinalphos etc., and in some samples they exceeded the MRLs. In addition, residues of banned pesticides like DDT, BHC, aldrin, tetradifon, etc. were also detected in the past. This shows that some of the tea estates are still unconcerned about the hazards already stated. Residues of DDT, BHC, aldrin, etc. can persist for very long periods. One must realize that if the problem of pesticide residues in tea continues, it will be impossible to promote tea as a health drink, and thus jeopardising not only export of Indian tea but also hampering the domestic consumption. One way of minimising the excessive residue problem is total rationalization of the pesticide uses and studying the pests behaviour more thoroughly so that an effective integrated pest management approach becomes feasible.

BIO-DEGRADATION OF PESTICIDES

There are many microorganisms and enzymes which can biodegrade synthetic pesticides to nontoxic metabolites. Examples are given in Tables 4 and 5. Exploitation of these agents in pesticide degradation has not yet been made in the field.

Table 4. Degradation of pesticides by microorganisms.

Microorganism	Pesticide
Bacteria	
Pseudomonas aeruginosa BS 827	Dicofol
Pseudomonas sp.	Malathion
Fungi	Fenitrothion
Fusarium, Aspergillus, Trichoderma sp.	
Actinomycetes	
Nocardia sp., *Streptomyces* sp.	Carbofuran

Table 5. Some important insecticide degrading enzymes.

Pesticide/Microorganism	Enzyme
Malathion	Carboxyesterases
Rhizobium leguminosarium	
R. trifolii	
Aspergillus niger	
Penicillium notatum	
Trichoderma solani	
Rhizoctonia solani	
Diazinon/Malathion	Cell free enzyme extract
Pseudomonas sp.	
Dimethoate/Malathion	Cell free enzyme extract
Arthrobacter sp.	
Chlorpyriphos	Phosphotriesterase, Phosphoesterase
Flavobacterium sp.	
Monocrotophos	Crude enzyme extract
Pseudomonas sp.	

Other adverse effects caused by indiscriminate and large scale use of these insecticides are development of insect resistance to insecticides, outbreak of secondary pests and toxicity on non target species. To overcome these problems, recently tea plant protection has shifted its objective towards practicing integrated pest management (IPM). IPM can be defined as a pest management system that in the context of the associated environment and population dynamics of the pest species utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury.

Practicing IPM does not preclude use of pesticides, but keeps it to a minimum level by judicious combination of other pest control methods like cultural, physical, mechanical, biological, genetic and regulatory control. It is based on sound knowledge of various factors relating to pest build up. population dynamics and their naturally occurring mortality factors as follows :

1. Identification of pest
2. Detail information on its developmental stages
3. Site of attack
4. Damage symptoms
5. Physiology of host plant i.e. flushing and non-flushing periods and inter flush dormancy
6. Alternate hosts
7. Mode of migration/dispersal

Information on biology of tea pests is presented in Table 1. This knowledge will help us to avoid the repeated sprays of the toxic chemicals and also to achieve expected control of pest with minimum insecticide use.

TOOLS OF IPM

Cultural Methods or Use of Agronomic Practices

1. Resistant clones should be identified against a specific pest and in those localities where that pest is epidemic. use of such a clone should be advocated for future planting in the extension areas and for replanting in the older sections

2. Crop rotation : Unlike agricultural systems, crop rotation is not possible. To improve soil productivity of the uprooted areas, *Guatemala* and *Mimosa* are used as the rehabilitation crops; this is some kind of a crop rotation.

3. Crop refuse destruction : Cold weather practices like knife/hand cleaning of the diseased and dead branches from the bushes eliminate hibernating pests like looper and bunch caterpillars. thrips. termites. etc. They also improve bush health and productivity. Removal of webs and dead and dying branches help in considerable reduction of common bark eating borer, common red borer, large stem borer, etc.

4. Soil stirring or forking around the collar region during November-December leads to the reduction in population of many pests like bunch and looper caterpillars, nettle grubs and gelatine or jelly grubs.

5. Pruning : Three year or four year pruning cycles are now-a-days followed. The current practice of keeping the plants unpruned for two to three years may provide suitable habitat for continuous build up of certain pests like red spider mite throughout the year and contribute enormously towards continuity of its generation and perpetuation.

6. Nutrition : Balanced nutrition improves vigour of the plant to withstand pest and disease attack. Pest infestation is reduced markedly in fertile soils. Tea grown soils in which the ratio of available potash to available phosphoric acid low suffer more from the tea mosquito bug.

7. Sanitation : Weed free cultivation of tea is emphasized strongly because weeds compete for nutrition and soil water. Some weeds smother the plucking surface. They also harbour pests and diseases (Table 6). All the vacant areas should be infilled to obtain full ground cover to suppress weed growth and thereby eliminate alternate hosts. Caustic washing of bush frame reduces attack of red slug caterpillar. psychids. common bark earing borer, etc.

8. Water management : Inadequate drainage creates conducive conditions for build up of red spider mite and tea mosquito bug.

9. Planting of trap crops : Trap crops attract and retain a pest species or provide a more favourable habitat to increase natural enemies. Such a work on this method of pest control has yet to be initiated in tea. But in a different form, trap cropping is practiced in tea and it has already produced limited success. For example, a few tea bushes are kept unpruned and unskiffed in a tea mosquito bug infested garden. They were sprayed with monocrotophos/phosphamidon/endosulfan after which they were skiffed or pruned. Some alternate hosts especially can be used as trap hosts.

10. Soil rehabilitation : Improvement of soil structure and nutrition by proper rehabilitation of soil prior to replanting is advisable. This will destroy survival link of soil borne pathogen and will also detoxify toxins/allelochemicals, etc.

11. Shade management : Absence of shade helps in rapid multiplication of red spider mite. Lack of shade also results in high leaf temperature and reduced soil fertility leading to poor health and decreased productivity. On the other hand, excessive shade leads to spread of diseases like black rot and blister blight. Bormedeloa should be avoided as a shade tree as it is susceptible to looper caterpillar.

12. Cold weather practices and bush sanitation : Certain cold weather practices like forking of soil around the collar of tea bush, ground levelling, filling up the collar depressions, alkaline wash of bush frames, knife/hand cleaning of the diseased and dead branches from the bushes have positive contribution towards reduction of pest build up like looper and bunch caterpillars, thrips, termite, etc. besides improvement of bush health for increasing productivity.

13. Soil amelioration : Ideal pH for tea growth is 4.5 - 5.5, but lower or higher than the range causes debility of bush due to imbalanced nutrition . The plant becomes susceptible to pest and disease attack.

Table 6. Some important weed hosts of N. E. Indian tea estates.

Weed hosts	Parasitic pests
Ageratum conyzoides	Root knot nematodes
Borreria hispida	Root knot nematodes and Scarlet mite
Commelina bengalensis	Root knot nematodes and Scarlet mite
Clerodendron infortunatum	Helopeltis and Scarlet mite
Melastoma malabathricum	Red spider mite, Scarlet mite and Helopeltis
Mikania micrantha	Helopeltis
Pouzolzia indica	Root knot nematodes and Scarlet mite
Urena lobata	Red spider mite
Oxalis corymbosa	Root knot nematodes

Mechanical Methods

1. Hand collection : It is a common practice for collecting caterpillars and chrysalids of various insect pests for minimizing their population to a great extent. Table 7 shows names of various pests against which mechanical control can be employed during different months. The most widely used mechanical method of tea pest control is the hand collection of caterpillars. chrysalids, pupae and adults; thereby reducing the population of many lepidopteran pests to a great extent. Collection and destruction of damaged parts are also suggested.

2. Collection of different insect pests specially by suction devices may not only provide useful data for population estimation. but it may reduce pest population substantially.

Physical Methods

Out of various physical methods utilized for pest control, light trap is the most common. This is utilized for catching moths of looper, bunch and red slug caterpillars during Feb-Mar and Jul-Aug, Sep-Oct and Dec-Mar and Mar-Apr and Jul-Aug. respectively. Fire can also help in reducing jassid population.

Regulatory Methods

Only healthy, disease and pest free planting materials should be used.

Table 7. Monthwise mechanical control schedule for tea pests

Pest	Stage	Period	Method employed
Bunch caterpillar	Larva	Oct-Nov, Mar-Apr	Hand collection
	Chrysalid	Nov-Dec	Hand collection
Red slug caterpillar	Larva	Nov-Apr	Hand collection
	Chrysalid	Dec-Feb	Hand collection
	Larva		Erection of barrier by spreading used engine oil in a line 160 cm wide along the edges of roads and paths of severely infested areas to prevent dispersion of larvae
Psychids	Larva	Sep-Nov	Hand collection
Nettle grubs	Larva	Apr-May	Hand collection
	Pupa		Hand collection during pruning
Looper caterpillar	Larva	Mar-Apr, Sep-Oct	Hand collection
	Chrysalid	Oct-Dec, Mar-Apr	Hand collection around collar region
	Moth	Feb-Mar	Hand collection from shade trees
Lobster caterpillar	Larva		Hand collection
Lymantrid caterpillar	Egg, moth with vestigial wings		Hand collection
Flushworm	Shoots with larvae inside		Hand collection and destruction
Leaf roller	Larva		Hand collection and destruction
Sandich caterpillar	Larva		Hand collection
	Pupa	Nov-Jan	Hand collection
Bark eating caterpillar	Larva		Rubbing with hessian cloth
Cockchafer	Adult		Hand collection
Tea mosquito bug	Egg	Dec-Jan	Hard plucking, removal and destruction of infested shoots
	Adult & nympth		Hand collection in the early morning or late in the afternoon
Aphid	Adult & nympth		Hand picking of the infested shoots
Tea seed bug	Adult & nympth		Hand collection

Biological Control

A number of natural enemies (predators, parasitoids and pathogens) are recorded against tea pests like red spider, bunch, looper and red slug caterpillar, flush worm, aphids, green fly, membracid, *Helopeltis*, scale insects, cockchafer grub and mole cricket (Table 8).

The procedure of their mass multiplication and subsequent release in tea fields needs further study. These are already included in ongoing research projects of TRA. Some of the commercial formulations of entomopathogens are already in the market. Encouraging results were obtained with introduction of *Bacillus thuringiensis* against bunch and looper caterpillars. However, precaution should be taken to ensure the use of this pathogen to the areas without any silk worm cultivation in the near vicinity.

To keep parasites and predators active in tea areas, less toxic selective pesticides should be preferred as far as possible. Toxicity of some popular pesticides on parasite/predator is given in Table 9.

Table 8 : Natural enemies of tea pests.

Tea pest	Natural Enemies
Red spider mite	*Verania vincta, Stethorus gilvifrons, Jaurevia* sp., *Scymnus* sp., *Verticillium* sp., ***Agistemus* sp.**, *C. hrysopa* sp.
Bunch caterpillar	Techinid fly, *Cantheconidea furcellata*, dipterous fly
Looper caterpillar	*Sarcophagus* sp., *Apantales* sp., bacterial disease
Red slug caterpillar	*Apanteles* sp.
Flush worm	*Apanteles* sp., *Asympiesella* sp.
Aphid	Eleven species of coccinellids, 6 species of syrphids and two parasitoids
Green fly	Drynid wasp
Membracid	*Beauvaeria bassiana, Sporothrix isarioides*
Helopeltis	Reduviid bug, *Oxyopes* sp., mermethid nematode, *Melamphaus* sp., *Sycanus* sp.
Scale insects	*Microterys* sp. *Comperiella bifasciata, Microdon bellus, Coccinella septempunctata, Aspidiotiphagus* sp., *Aphytis* sp., *Coccophagus* sp., *Anagyrus* sp.
Cockchafer grub	*Gliocladium roseum*
Mole cricket	*Paecilomyces carneus*

Table 9. Toxicity of some pesticides on parasites and predators.

Pesticides	Less toxic	Moderately toxic	Highly toxic
Endosulfan & Fluvalinate	Parasitic wasp., coccinellid		
Quinalphos	*Agistemus* sp.	Coccinellid, Parasitic wasp	
Phosphomidon	Coccinellid adult		Coccinellid grub
Dicofol	-do-		
Ethion	-do-	Coccinellid wasp	*Agistemus* sp.
Cypermethrin & Alphamethrin			*Agistemus* sp., *Phytoseiulus*
Fluvalinate	*Agistemus* sp., coccinellid, *Menochilus sexmaculata* and *Leis dimidiata*		

Chemical Control

Insecticides : Chemicals used for containing insect pests are called insecticides; they must have certain desirable qualities in terms of toxicity, safety to natural enemies and environment. Therefore, to provide rationale for intelligent choice of insecticides by the planters as well as pest management specialists, an overall evaluation of the suitability of each compound seems to be both desirable and useful. Such rating is called pest management rating (PMR). By following standard method, PMRs have been devised for common insecticides registered for and widely used on tea in N.E. India in regard to their safety and overall effects on environmental quality. It is based on average performance in (a) acute toxicity to man and domestic animals, (b) overall toxicity to pheasant, rainbow trout and honeybee (environmental indicator organisms) and (c) environmental persistence. A rating of 1 to 5 with increasing hazard was assigned.

1. Mammalian toxicity was rated from rat oral LD_{50} in mg/kg as follows :

1	=	> 1000
2	=	> 200 - 1000
3	=	50 - 200
4	=	10 - 50
5	=	< 10

2. Non target toxicity was rated as the average of individual ratings for :

Pheasant oral LD_{50} (mg/kg)	Rainbow trout 48 hr/LC_{50} (ppm)	Honeybee Topical LD_{50} (mg/kg)
1 = > 1000	1 =>1.0	1 =>100
2 = 200 - 1000	2 = 0.1 - 1.0	2 = 20 - 100
3 = 50 - 200	3 = 0.01 - 0.1	3 = 5 - 20
4 = 10 - 50	4 = 0.001 - 0.01	4 = 1 - 5
5 = < 10	5 =<0.001	5 =<1

3. Environmental persistence was rated as the approximate average soil half life :

1 = < 1	month
2 = 1-4	month
3 = 4-12	month
4 = 1-3	years
5 = 3-10	years

The combined ratings for each of the insecticides and acaricides are presented in Table 10.

Table 10. Pest management rating of tea insecticides/acaricides.

Acaricide/ insecticide	Mammalian toxicity	Non target toxicity				Environmental persistance	Overall rating
		Fish	Bird	Honeybee	Average		
Dicofol	2	1	2	1	1.3	4	7.3
Ethion	3	2	3			2	7.0 *
Carbofuran	5	2	5	5	4.0	3	12.0 *
Dimethoate	3	1	4	5	3.3	2	8.3
Chloropyriphos	3	3	3	5	3.7	3	9.7 *
Endosulfan	4	4	2	2	2.7	3	9.7
Malathion	2	2	1	4	2.3	1	5.3
Phorate	5	4	5	2	3.7	3	11.7
Phosalone				1			
Phosphamidon	4	1	5	3	3.0	2	9.0
Deltamethrin	1	2	1	2	1.3	1	3.3*
Fluvalinate				1			
Cypermethrin	1			2			
Fenvalerate				1			

* Information not sufficient

Use of botanical products : Neem has been found to have multifarious activity like antifeedant, repellent, toxicant, growth inhibitory, antiovipositional, etc. Conservative estimates suggest that it affects more than 300 pest species. This is an effective alternate pesticide in IPM. *Azadirachta indica* seeds are a rich source of azadirachtin. From seeds of *Melia azedarach* (bocaine) meliantriol was isolated and found to be an effective antifeedant for locusts. These need proper evaluation for use in tea.

Various neem formulations, which have been approved to be used against tea pests, are Godrej Achook (1:100), Neem gold (1:150) and Neemazol F (1:1500). The former two can be cocktailed with conventional pesticides like endosulfan, phosalone, Dicofol and ethion.

Hormonal control : Insect growth regulators (hormones) can be effectively employed for affecting adversely the normal growth and behaviour of tea pests. Growth regulator like Dimilin found to be biologically effective to hinder the normal growth of caterpillars. Full grown larvae of bunch and looper caterpillars fail to pupate. Two chitin inhibitors like Cascade and Phomolt also showed very good results against bunch and looper caterpillars.

Attractants repellants and sterilants : These are a few chemical tools which are yet to be tried either in the laboratory under R & D activities or in the field. These may in certain cases prove to be potential in solving difficult pest problems.

Conclusion

1. Pesticide residues in made tea will have to be minimised by judicious use of pesticides.
2. Residues of all chemicals need to be established in made tea and also in hot water infusion by the producing countries for assigning realistic MRL value.
3. Tea is a health drink and, therefore, integrated pest management strategy must be employed by all producing countries to ensure minimum use of pesticides.
4. Neem products of proven quality and other bioagents should find place in the pest management system.
5. Physical, mechanical and cultural methods should receive maximum attention to control pests and diseases in tea.
6. While switching over to IPM, the initial cost is likely to be more but it will pay in the long run.
7. Constant pest monitoring is an important aspect in IPM system.
8. No integrated pest management system succeeds if there is no quality control in field management practices.

BIOLOGY AND CONTROL OF MAJOR TEA AND SHADE TREE PESTS

Karan Singh and Monorama Borthakur

The concept of pest control has undergone a considerable change over the past few decades. The growing concern about the pesticide residue in made tea, its toxicity hazards to consumers, the spiralling cost of pesticides and their application have necessitated a suitable planning which will ensure a safe, economic as well as effective pest management in tea and shade trees.

BASIC REQUIREMENTS

Efficient pest management depends upon sound knowledge pertaining to the following :

1. Identification of the pests and their damage symptoms
2. Biological information
3. Pest surveillance
4. Time of application
   a) Control measures during lean period will ensure reduced pest activity in the main cropping season.
   b) Application of pesticide in the initial stage of pest build up will prevent wide spread incidence.
   c) Spraying should be avoided during the hot sunshine hours of the day.
   d Spraying should be done immediately after plucking.
5. Selection and dilution of pesticide
   a) Pesticides having clearance from EPA and from other international agencies should only be used in tea during the plucking season.
   b) Recommended dilutions should be used. Both under and over doses of pesticides should be avoided.
   c) Relevant publications like latest Pesticidal Recommendations (*Wall Chart*), Spraying Schedule, IPM and Two and A Bud should be consulted.
6. Genuineness of pesticides

   Pesticides should always be purchased from the authorised dealers, and in case of any doubt, 100 ml of the pesticide properly packed and labelled with particulars such as batch no., date of manufacture, date of expiry and source of purchase should be sent to Tocklai for bio-efficacy test.
7. Toxicity and compatibility of pesticides

   Only TRA recommended pesticides should be used. Mixing of two pesticides may not be compatible and may give rise to metabolites which may be more toxic than the original compound. Compatibility chart in the T.E. Serial No.110/5 under J3 should be consulted.
8. Supervision

   The efficiency of spraying depends on supervision at the time of preparation of spray fluid and spraying. Effective pest control is possible only when properly prepared spray fluid is sprayed thoroughly over the target. Pesticidal solution once made should be used immediately.

MITE PESTS

Larvae, nymphs and adults cause damage by sucking the sap.

Damage Symptoms

Red spider (*Oligonychus coffeae*) : Reddish spots develop on the sucking sites which subsequently unite to form large brown patches. Red spider occurs mostly on the upper surface of the leaves.

Scarlet mite (*Brevipalpus phoenicis*) : General yellowing of leaves and brownish discolouration of the midrib on the undersurface. Bark of the affected stems may also split. Scarlet mite occurs mostly on the undersurface of the leaves.

Pink mite (*Acaphylla theae*) : Affected leaves become pale, dry and leathery. Veins and margins on the undersurface show pinkish discolouration. Pink mite occurs mostly on the undersurface of the leaves.

Purple mite (*Calacarus carinatus*) : Leaves turn purplish-bronze, dry up and fall off. Cast-off skins of the mites give the impression as if the leaves are dusted with white particles. Purple mite occurs mostly on the upper surfaces of the leaves.

Biology

Red spider (*Oligonychus coffeae*) : Spherical and red eggs are laid on leaf surfaces. The eggs hatch in 4-6 days during the summer months. The life-cycle is completed in 10-14 days during the summer months.

Scarlet mite (*Brevipalpus phoenicis*) : Eggs are laid on the undersurface of the leaves, midrib and veins. The eggs (elliptical and bright red) hatch in 11-13 days in March, 8-9 days in April and 6-7 days in July. The life-cycle is completed in 24-28 days in March and 21-25 days in April under laboratory conditions.

Pink mite (*Acaphylla theae*) : The eggs are laid singly on surface of the leaf; they are colourless and globular in shape but with shining surface.

The incubation period is 6-7 days in December and January, 3-4 days in March and about 2 days in July and August. The life-cycle is completed in about 8 days in March, 6 days in July and August and 13 days in December and January under laboratory conditions.

Purple mite (*Calacarus carinatus*) : The eggs are laid singly on surface of the leaves. These are colourless, almost transparent and circular in outline. The egg stage is 6-8 days in January, 4-5 days in March and 3-4 days in July and August. The nymphal stage is 5-6 days in January, 4-5 days in March and April, and 3-4 days in July and August. The life-cycle is completed in about a week in July and August while, in December and January the life-cycle is completed in a fortnight.

SUCKING INSECTS

Tea Mosquito Bug (*Helopeltis theivora*)

Nature of damage : **Damage is caused by the nymphs and the adults. Initially, a ring like spot is formed at** the site of sucking. This turns into translucent light brown spot within 24 hours. Later on the spots appear as dark brown sunken spots and dry up. An adult can produce about 100 such spots within 24 hours.

Biology : Eggs are laid inside the tissues of the tender stem, midrib and petioles of leaves. The egg stage may vary from 4-20 days. A bug lays 4-5 eggs per day. A single female may lay more than 200 eggs. The life-cycle is completed in 10-35 days.

Tea Thrips (*Scirtothrips dorsalis*)

Nature of damage : **Thrips (nymphs and adults) cause damage to the tender leaves by laceration and** sucking the juice that oozes out from the damaged tissues. The initial symptom of attack is light brownish

discolouration of the tip and the basal part of leaves. Later on 2 or 4 sand papery lines appear on either side of the midrib. Badly damaged leaves appear rough, deformed and curled. Shoot growth is retarded with corky tissues on the bark. Droughty spell encourages rapid build-up of thrips population.

Biology : Eggs are laid singly inside the tender plant tissue, particularly on leaf, midrib, vein and bud. Pupation takes place in the cracks and crevices of the stem and also in the soil. The life-cycle is completed in about three weeks during June-July.

Tea Jassids (*Empoasca flavescens*)

Nature of damage : **The nymphs and adults suck the sap from the growing shoots as a result of which the** growth of the shoot is retarded and the leaves curve inward; the margins become recurved and subsequently turn brown and dry up. The midrib and the veins of the leaves turn brownish.

Biology : Eggs are embedded inside the tender stem of leaf bud, petiole, midrib, veins and intervenal spaces. The eggs hatch in 6-13 days. The life-cycle is completed in 14-25 days.

LEAF EATERS

Looper Caterpillar (*Buzura suppressaria*)

Nature of damage : **The young caterpillars make holes along the margins of the leaves by nibbling while** the subsequent instar caterpillars eat away the entire leaves. In severe cases, bushes may be completely defoliated.

Biology : Bluish green eggs covered with buff coloured hairs are laid on the trunk of the shade trees and hatch in 8-9 days into black caterpillars. The larval stage is about 24-36 days. Full grown caterpillars pupate in the soil at a depth of 5-10 cm. The pupal period is 20-22 days.

The caterpillars appear in the field from March to October (Table 1).

Table 1 : Time of occurrence of different stages of looper caterpillar.

Moths	Caterpillars	Chrysalids
End Feb-Early Mar	Early Mar-3rd week of Apr	Early Mar-1st week of May
Early Mar-Mid May	Mid May-3rd week of Jun	End Jun-1st week of Jul
Early Jul-Mid Jul	Mid Jul-Mid Aug	End Jul-End Aug
Mid Aug-Early Oct	Early Sep-Mid Oct	End Oct-1st week of Nov

Red Slug Caterpillar (*Eterusia magnifica*)

Nature of damage : **The early instar caterpillars feed on the epidermal tissues and skeletonise the mature** leaves on the lower part of the bush. Later on the grown up caterpillars migrate to the top hamper and feed on the margins of the leaves. In severe infestation, the bushes may be defoliated and the bark may also be damaged.

Biology : Oval and pale yellow eggs are laid on the undersurface of the leaves and on stems. The eggs hatch in 8-12 days during May-June. The larval and the pupal stages occupy 4-5 and 2-3 weeks respectively. The life-cycle is completed in 8-10 weeks in the summer months (Table 2).

Table 2 : Time of occurrence of different stages of red slug caterpillar.

Moths	Caterpillars	Chrysalids
Dec - Mar	Feb - Apr	Feb - May
May - Jun	End June-End July	Jul - Aug
End Jul-Early Aug	Aug-End Sep	Sep - Oct
Sep - Oct	Nov - Jan	Nov - Feb

Bunch Caterpillar (*Andraca bipunctata*)

Nature of damage : The young caterpillars feed on the epidermal tissues and at the margins, while the later instar caterpillars devour the entire leaves. The caterpillars remain in clusters during day hours. They become active after sunset and migrate to adjacent bushes after defoliating these.

Biology : Oval shaped yellow eggs are laid on the undersurface of leaves in rows. The eggs hatch in 10-11 days in summer. The life-cycle is completed in 8-9 weeks in March-June (Table 3).

Table 3 : Time of occurrence of different stages of bunch caterpillar.

Moths	Caterpillars	Chrysalids
Mid Mar-Early Apr	3rd week of Mar to mid Apr	3rd week of Apr to May
Mid May-Early Jun	3rd week of May to mid Jun	3rd week of Jun to mid Jul
Mid Jul-Early Aug	3rd week of Jul to mid Aug	3rd week of Aug to mid Sep
Mid Oct-Early Nov	3rd week of Oct to mid Dec	3rd week of Nov to early Jan

TERMITES

Young and mature tea as well as cuttings in the V.P. nursery are often damaged considerably by the live wood eating *Microcerotermes* sp. and the scavenger termite, *Odontotermes* sp. The initial termite activity starts from September and termite prone areas should be kept under vigilance from the end of August.

The live wood eating termites form innumerable small nests in the soil usually 8-20 cm below the soil surface, while the nests of the scavenger termites though subterranean in nature may be situated at a far off place even outside the infested section. The mounds of the mound building termites are located generally inside the infested section. The queens of the termites produce eggs every second and hence for effective control of termites the queens must be killed. it is desirable that the chemicals go down the soil to reach the royal chamber where the queen lives.

NURSERY PESTS

Plant parasitic nematode or eelworms :

Root-knot nematodes : *Meloidogyne incognita, M. javanica, M. hapla, M. brevicauda*

Root-lesion nematodes : *Pratylenchus brachyurus, P. loosi*

Nematodes are soil borne pests.

Four species of root-knot nematodes and two species of root-lesion nematodes were recorded on tea causing damage to seedlings and the root system of young plant up to the age of three years. While the root-knot nematodes frequently occur in the nursery soils, the occurrence of root-lesion nematode is rare.

The 2nd instar larvae of root-knot nematode damage tea root system, if the soil that is used for nursery is infested with this nematode. Nematodes are microscopic, not visible with naked eye or hand lenses. The life-cycle consists of egg, four larval and adult stages. Sandy-loam type soil is the best for multiplication of nematodes.

Damage Symptoms

Root-knot nematode : (i) Stunted growth of the plant, (ii) chlorosis or yellow discolouration of leaves, wilting of plant in summer, (iii) innumerable swellings or galls form on the roots. Tap root becomes swollen, rotten with minute holes.

Root lesion nematode : (i) Stunted growth of plant, (ii) formation of brown coloured lesion or wound in the root.

Control measures

Cultural practices : **(i) Soil from the nursery site should be tested for eelworm population and acidity -** status. If the population of eelworm is found to be 6 or above per 10 g of soil tested, it is considered to be unsuitable for use, (ii) Cultivation work (Ploughing and harrowing) for preparing the nursery bed should be done to expose and dry the undecomposed weeds and roots of the plants. All sorts of mulch materials should be kept away from the seed nursery to avoid nematode infestation, (iii) Plant parasitic nematodes can be killed by uniform heating (after sieving) of the soil up to 60°-70°C for 4-5 minutes on plain tin sheets. The soil can be used after heat treatment. (iv) Remove weed hosts from nursery beds.

Chemical control : Apply Furadon 3G @ 1 g/plant/sleeve before or after planting. Apply after one month at the same rate. Each application should follow sprinkling of water for quick absorption.

Complete eradication of nematode by chemical treatment is not possible, and it is also not cost effective. As such testing of the soil before use is the best measure to avoid nematode infestation.

SHADE TREE PESTS

FOLIAR PESTS

Green Caterpillar (*Rhesala moestalis*)

The leaflets of *Albizzia odoratissima*, *A. procera*, *A. chinensis* are attacked by the caterpillars which tie up the leaflets and feed from inside. Young plants may be defoliated completely in the process.

White, flat and circular eggs (0.5 mm) are mostly laid singly on the undersurface of the leaflets. The incubation period is 7-8 days.

The freshly emerged caterpillar is pale yellow and measures 1.5-2.0 mm in length, while the full grown caterpillar is green with brownish yellow head and measures 17-20 mm in length. The larval period occupies 10-15 days. Pupation takes place in the soil and the brown pupa measures 9.5-10.5 mm in length. The pupal period is 6-10 days. The life cycle is completed in 3-4 weeks.

The pest is found in the field from March to November with the peak of incidence in the month of June.

Pierid Caterpillars

Pierid caterpillars of *Eurema blanda silhetana* and *E. hecabe* eat away the leaflets of *A. odoratissima*, *A. chinensis*, *A. lebbek* and *A. falcata*. Young and nursery plants may be defoliated completely. However, in an attack of pierid caterpillars of *Catopsilia crocale* the young plants of *Cassia siamea* and *C. fistula* are often completely defoliated.

Eurema blanda silhetana : White, spindle shaped eggs (1.5 mm in length) are laid in cluster on the undersurface of the leaflets. The eggs hatch in 6-7 days in March and 12-14 days in December.

The just hatched caterpillar (1.6-1.9 mm in length) is white with a black head, while the full grown caterpillar (20-30 mm in length) is green with a black head.

The larval period occupies 11-14 days in March and 22-26 days in December. Pupation takes place in clusters on the rachis and midrib of the leaves of the defoliated plants. The pupa (17-20 mm in length) is triangular and olive green in the beginning, turning to brown to black later on. The pupal period is 6-7 days in March and 11-14 days in December.

The life-cycle is completed in 23-28 days in March and 45-54 days in December.
The pest is active in the field from November to March and virtually disappears during the summer months.

Eurema hecabe : The incubation period is 9-10 days in February and 3 days in July and September.

The larval period is 20-23 days in February and 10-14 days in June and September. The pupal period is 11-12 days in February and 5-6 days in June and September. The life-cycle is completed in 40-45 days in February and 18-23 days in June and September.

The pest is prevalent from February to September.

Catopsilia crocale : Eggs (1.3 mm in length) are white, spindle shaped and laid singly on both the surfaces specially on the margins. Later on the colour of the eggs changes to light yellow.

The incubation period is 2 days in June and September and 7 days in March.

The newly emerged caterpillar (2.25 mm in length) is pale yellow with similar coloured head, while the full grown green to yellow green caterpillar measures about 43 mm in length. The larval period occupies 7-8 days in June and September and 16-17 days in March.

Pupation takes place on the rachis and midribs of the leaflets. The pupa is boat-shaped, green or light gray in colour and measures 27-28 mm in length. The pupal period lasts 5-6 days in June and September and 8 days in March.

The life-cycle is completed in about a month in March and 14-16 days in June to September.

Bihar Hairy Caterpillar (*Diacrisia obliqua*)

The young caterpillars feed on the epidermal tissues of leaves, while the full grown caterpillars eat away the entire leaves of *Indigofera teysmanii*.

Yellowish green spherical eggs (0.5 mm in length) are laid in clusters on the undersurface of the leaves. The eggs hatch in 5-13 days. The full grown caterpillar is about 25-37 mm in length.

The larval period is 23-36 days.

Pupation takes place in the ground on the dry fallen leaves. The pupal period is 9-10 days.

The life-cycle is completed in 5-7 weeks.

The pest is prevalent in the field from February to September with peak in June.

White Caterpillar (*Boradesa omissa*)

The caterpillars are found to defoliate the leaves of *Dalbergia assamica* and *Derris robusta*.

The full grown caterpillar (40-50 mm in length) is greenish white with a white head. On the lateral sides of the body there is an interrupted black line with a pair of yellow and white lines below.

The pupation takes place in the soil. The reddish brown pupa is about 3 cm in length.

The pupal period lasts for 2-3 weeks. Eggs are laid in clusters in cracks and crevices on the branches of the trees. Clusters are covered with the scales of the moth. The pest is prevalent from March to November.

Semi-looper Caterpillar (*Pericyma umbrina*)

The caterpillars cause extensive damage to *Acacia lenticularis* and occasionally to *A. odoratissima* and *A. lebbek*.

The full grown caterpillar is light yellow with white longitudinal lines dorsally and black broken lines on the sides. The head is reddish brown. Pupation takes place in the soil.

Looper Caterpillar (*Buzura suppressaria*)

The caterpillars feed on the foliage of *A. odoratissima, A. lebbek, Dalbergia assamica* and *Indigofera* teysmanii *for some time and then descend to the tea bushes below to complete the rest of the larval stage and* ultimately pupate in the soil.

Blue Beetle (*Trichochrysea hirta*)

The metallic blue beetle (9 mm in length) causes considerable damage to the new growth of *A. odoratissima, A. chinensis, A. procera, A. falcata* and *A. lucida* from April to September.

Plant Lice or Psyllids (*Pshylla oblonga*)

Psyllids are small green sucking insects (1-2 mm in length) and breed throughout the year on the foliage of young *Albizzia procera* and *A. lebbek*. Plants above 1.5 metres are scarcely attacked.

The affected leaves present a rosette appearance and the growth of the plant is retarded. The plants may die.

Black or gray spindle shaped eggs (0.35 mm) are laid singly or in clusters on both surfaces of the leaflets as well as on the leaf margins.

The life-cycle is completed in 2-3 weeks time during the summer months.

Tree Hopper or Membracid (*Oxyrachis terandus*)

The petioles and the tender stems of *A. odoratissima, A. chinensis, A. procera, A. lebbek* and *C. fistula* plants are attacked by the nymphs and adults of membracid throughout the year. As a result of sucking, the plants get stunted and die-back. Translucent white eggs are embedded on the succulent stems in a 'V' shaped formation; the colour changes to pale yellow later on.

The incubation period is 27-29 days in November-December and 51-52 days in December-January.

The nymphal stage lasts for 31-33 days in July-August and 82-87 days in November-February.

The life cycle is completed in 3-5 months.

PESTS OF TRUNK AND MAIN BRANCH

Canker Causing Insects

Larvae of *Agrilus beesoni* and *Cryptorrhynchus* sp. cause extensive damage to the main trunk and side branches of *A. odoratissima, A. chinensis, A. procera, A. lucida* and *A. lebbek* by making irregular tunnels and galleries in the bark. As a result, gummy substances are exuded from the sore.

The adults lay eggs in cracks and crevices on the main stem or the side branches during March-April and August-September.

The full grown grub of *Agrilus* is white with a small brown head (8-10 mm in length), while the full grown grub of *Cryptorrhynchus* is creamy white with a yellow head (6-7 mm in length).

Grubs of *Agrilus* are abundant from March to September while both grubs and adults of *Cryptorrhynchus* sp. are found in the field throughout the year.

The life-cycle of *Agrilus* is completed in about 4-5 months.

Bark Eating Caterpillar (*Inderbela quadrinotata*)

The bark eating caterpillars cause extensive damage to *A. odoratissima*, *A. chinensis*, *A. procera*, *A. lebbek* and *Acacia lenticularis*.

The eggs are laid in clusters in cracks and crevices on the bark of the shade trees during April-June.

On hatching the larva bores a short tunnel downwards into the wood at the junction of a dead branch or snag to use it as a shelter. The larvae feed on the outer layer of the bark causing irregular tunnels. The feeding area is covered by the caterpillar with a brownish web made of bark fragments, facial matters and silk. On the slightest disturbance the caterpillars retreat into the holes. The full grown caterpillar measures 40 mm in length.

Pupation takes place in the retreat holes during March. The moth emerges in April-May.

Stem Borer (*Xystocera festiva*)

The cerambycid grubs cause extensive damage to the stems of *A. odoratissima*, *A. lebbek*, *A. falcata* and *Derris robusta*. The top branches show die-back in mature plants. Peeling-off of bark from the collar to the top followed by die-back symptoms indicate the presence of cerambycid attack.

The beetle emerges during February-March and again during September-October.

ROOT DAMAGING PESTS

Buprestid beetle (*Sternocera aurosignata*) is commonly known as Sona poka. Grubs cause damage to the tap root of *A. odoratissima*, *A. chinensis*, *A. procera*, *A. lebbek*, *A. falcata* and *Acacia lenticularis*. The grubs girdle the tap roots from bottom upwards. Tap roots of the seedlings are completely eaten away. When the tap roots become big and hardy, the grubs bore into them. The leaves of the affected plants turn yellow and droop down. In a severe attack the growth is retarded and the plants may die.

Brownish pea shaped eggs (6 mm in length) are laid in the soil near the collar of young and nursery plants during September-October. The newly hatched larva (February-March) is soft creamy white and 10-15 mm in length while the full grown grub is 50-77 mm in length. The larval period occupies 116-201 days. The full grown grub constructs a mud cell inside which the grub pupates. The pupal period is 2-3 months. The life-cycle is completed in about a year.

CONTROL MEASURES FOR TEA PESTS

MITES

Cultural Practices

1. Plant Shade if it is lacking.
2. Maintain weed free ground.
3. Protect the foliage on road side sections from dust by growing hedges. *Phlogacanthus thrysiflorus* (titaphool) is not susceptible to red spider attack and can be used as Hedge.
4. Pluckers should not enter into uninfested areas from infested areas.
5. Cattle trespass increases red spider spread.

Chemical Control

Red spider and scarlet mite

Mid Jan - mid Feb : Sultaf/Sulfex 80 WP @ 1:100 (H.V.), Four Star Wetsulf 40 EC @ 1:200 (H.V.) or Ultrasulf 80 WP @ 1:200 (H.V.) to be followed by Dicofol 18.5 EC/Ethion 50 EC @ 1:400 (H.V.) or 1:200 (L.V.) after 2-3 weeks.

Note : For unpruned/skiffed teas.

Mar - Jun	:	Monthly one round if necessary. Bioneem (0.03) 1:150 (H.V.) or Fartunaza (0.15) 1:200 (H.V.) or Azadirachtin (0.3) 1:300 (HV). Sulphur formulations can be used in between.
Jul - Nov	:	Spot application in infested patches. Bioneem (0.03) 1:150, Fortunaza (0.15) 1:200 or Azadirachtin (0.3) 1:300 + Dicofol 18.5 EC/Ethion 50 EC @ 1:600 (H.V.)

Pink mite

Early to mid Feb	:	Sulphur formulation
Apr - May	:	Monthly one round, if necessary, of Bioneem (0.03) 1:150, Azadirachtin (0.3) 1:300 or Fortunaza (0.15) 1:200
Jul - Nov	:	Spot application, when necessary, of neem product + Dicofol 18.5 EC or Ethion 50 EC @ 1:600 (H.V.)

Purple mite

Mid to end Jan	:	Dicofol 18.5 EC/Ethion 50 EC @ 1:400 (H.V.) or 1:200 (L.V.)
Feb	:	Sulphur formulation
Jul - Nov	:	Spot application only of Fortunaza (0.15) 1:200 (H.V) or Bioneem (0.03) 1:150 (H.V) or Azadirachtin (0.3) 1:300 (H.V) + Dicofol 18.5 EC or Ethion 50 EC @ 1:600 (H.V)

SUCKING INSECTS (Helopeltis/Thrips/Jassids)

Cultural Practices

1. Prune/deep skiff sections in which patches were heavily infested last year by Helopeltis.
2. Remove weeds and other alternate hosts.
3. Black plucking in badly infested areas to be followed by spraying against Helopeltis/Thrips.
4. Soil stirring in December - March to destroy pupae of thrips.
5. Alkaline wash removes lichens and mosses from the bush frame, along with the pupae of thrips. This can be made by mixing the following :

Washing Soda	-	6 kg.
Quick Lime	-	2-3 kg.
Water	-	100 litre

Use hand sprayer/foot sprayer with broad cone nozzle.

Chemical Control

Early Jan	:	Monocrotophos 36 SL/Endosulfan 35 EC/Chlorpyriphos 20 EC/Quinalphos 25 EC @ 1:400 (H.V.) or 1:200 (L.V.) or Phosphamidon 85 EC @ 1:1000 (H.V.) against Helopeltis, to be followed by 2nd round after 2-3 weeks with Endosulfan 35 EC/Monocrotophos 36 SL.
Mar - Jun	:	Monthly one round when necessary of Bioneem (0.03) 1:150 (H.V) or Azadirachtin (0.3) 1:300 (HV) to be followed by Endosulfan 35 EC @ 1:400 (H.V), if necessary.

Jul - Nov : Endosulfan 35 EC @ 1:400 (H.V.)/Fortunaza (0.15) 1:200 (H.V) for one round, if necessary.

If necessary apply a round of Alphamethrin 10 EC @ 1:2000 (H.V.), Fluvalinate 25 EC @ 1:2000 (H.V.), Padan 50 SP or Trebon 10 EC @ 1:2000 (H.V.) during Jul to Sep against Helopeltis.

LEAF DEFOLIATORS (Looper, Red slug & Bunch caterpillars)

Cultural Practices

1. Mark out infested sections.
2. Collection & destruction of Chrysalids

   Looper : From soil during Dec - Feb.

   Red slug : From fork of bush/leaf fold or dry fallen leaves/ pruning litter on ground during Nov - Feb.

   Bunch : From dried leaves on ground during Nov - Jan.
3. Trapping of moths

   Looper : Hand collection or light trapping during Feb - Mar and Aug - Oct.

   Red slug : Hand collection or light trapping during Nov - Jan and Feb - Apr.

   Bunch : Hand collection or light trapping during Oct - Nov and Mar - Apr.
4. Collection of caterpillars

   Looper and red slug : Hand collection in early stage or in case of a Red slug minor attack.

   Bunch : Hand collection during day time when they remain in clusters.

Chemical Control

1. Against looper and red slug caterpillars

   Feb - Apr : Endosulfan 35 EC/Monocrotophos 36 SL @ 1:400 (H.V.) or 1:200 (L.V.)

   May - Jul : Fortunaza (0.15) 1:200 (H.V.) or Bioneem (0.03) 1:150, or Azadiractin (0.3) 1:300 or Endosulfan 35 EC @ 1:400 (H.V.)

   Aug - Jan : As in May - Jul.

   In severe attack apply a round of Deltamethrin 2.8 EC or Cypermethrin 25 EC @ 1:2000 (L.V.) or 1:4000 (L.V.) against late instar and early instar caterpillars respectively during Feb - Apr and Jul - Aug.

2. Against bunch caterpillar

   Mar - Apr : Endosulfan 35 EC/Monocrotophos 36 SL @ 1:400 (H.V.) and 1:200 (L.V.)

   May - Aug: Spot application of Endosulfan 35 EC/Monocrotophos 36 SL @ 1:400 (H.V.)

   Oct - Dec : Spot application of Endosulfan 35 EC/Monocrotophos 36 SL @ 1:400 (H.V.) and 1:200 (L.V.)

TERMITES

Cultural Practices

1. Bushes should be properly cleaned out at the time of pruning by removing the snags and dead and diseased branches.
2. Paint the pruning cuts with indopaste
3. Improve drainage condition.

4. Improve shade status.
5. Destroy termite mounds and the queen.

Chemical control

Sep - Oct	:	Initial infestation in the sections due for pruning and in young tea should be treated with Endosulfan 35 EC or Chlorpyriphos 20 EC 1:300.
Dec - Feb	:	Endosulfan 35 EC or Chlorpyriphos 20 EC @ 1:300 at monthly interval @ 60 ml/plant for young plant and 250 ml/plant for mature tea.

CONTROL MEASURES FOR SHADE TREE PESTS

Chemical Control

Pests of Foliage and Tender Stems

Spraying with a conventional pesticide 1:200 (L.V.) or 1:400 (H.V.), or with synthetic pyrethroid 1:2000 (L.V.) against full grown caterpillars or 1:4000 (L.V.) against early instar caterpillars.

Spraying of tea bushes below is a must before spraying against looper and semi-looper in shade trees.

Pests of Trunk and Main Branches

1. Brush the exposed part with a solution of 0.5 litre of insecticide and 115 g of fungicide in 50 litres of water. Paint the surface after a week.
2. Spray the trunk during Mar - Apr and Sep - Oct to prevent egg laying.
3. Apply granular insecticide @ 25/30 g per plant in 6-8 holes 30 cm away from the collar. Plug the hole after the putting granules and sprinkle a little water.
4. Against bark eating caterpillars, put a little insecticide solution into the retreat hole and then plug the hole with mud paste; repeat application after 2 weeks if fresh web is noticed. Alternatively, apply granular pesticide as stated above.
5. Against stem borer, spray the trunk during Feb - May at 2 weeks interval to prevent egg laying with a recommended pesticide, or apply a granular pesticide.

Root Pest

Apply recommended pesticide solution around the collar region during Feb - Apr.

CULTURAL PRACTICES

Agrilus and *Cryptorrhynchus* sp.

Strip off the affected patch and destroy larvae/pupae inside.

Bark Eating Caterpillar

Remove the webs before putting the insecticide solution.

Stem Borer

1. Remove dead and unproductive branches.
2. Uproot and burn dead plants to prevent migration of adults.

RECENT TRENDS IN TEA DISEASE MANAGEMENT

B. K. Dutta and B. K. Barthakur

Integrated disease management is one of the latest concepts in the field of modern Plant Pathology. In recent years it has been successfully employed in tea as well. However, in last few years a great attention has been paid for using the residue free bioformulations. These combined with better field management practices help in reducing the load of toxic fungicides and thus chances of health hazard.

Tea plants in N. E. India are susceptible to two groups of disease causing organisms viz. fungi and algae. Although more than 190 fungi have been so far recorded from this region, fortunately only a few of them are pathogenic to tea plants.

All parts of the tea plant are liable to attack by the above groups of pathogens, and depending on the mode of infection the diseases are divided into two groups viz. Primary and Secondary.

The primary diseases can attack and cause death to healthy plants. The secondary diseases on the other hand can be harmful only when the health of the bush is impaired due to certain stresses. The important aspect in the control of secondary diseases, therefore, lies in proper identification of the predisposing factors and measures for their rectification. Control of primary diseases depends mainly on chemical treatment, the success of which again depends on the proper understanding of biology of the disease causing organisms.

Some of the important diseases are discussed below.

SEEDLING DISEASES

Apart from blister blight, nursery plants are attacked by two parasitic fungi. Damping off caused by *Pythium* sp. follows waterlogged condition, whereas collar rot (*Phomopsis* spp.) is known to attack the plants during dry period. However, both these are of rare occurrence now a days and can be controlled by spraying copper fungicide.

LEAF DISEASES

Blister Blight

Blister blight is a seasonal disease and can spread very rapidly by means of spores which are produced in thousands in a single blister spot. Mature tea in general and teas recovering from pruning in particular suffer from blister blight. The fungus attacks young succulent growth on all teas specially when the environment is foggy, moist and cool. Spores are carried by wind and a single spore can produce a blister when deposited on tender shoots in about 10-21 days from the time of infection. The main periods of outbreak in different tea growing areas are as follows :

Darjeeling	-	July to September
Assam	-	March to May and November to December
Dooars	-	September to November

Control measures : Copper fungicides containing 50 per cent metallic copper are effective in controlling the disease during the peak infection period. It is sprayed at the rate of 625 g/ha in 100-150 litres of water with a motorised sprayer or at 0.125 per cent concentration (1:800) with hand operated sprayer. Two to three fortnightly rounds of hexaconazoles at 200 ml/ha with a low volume sprayer are also equally effective. In tea under plucking, the spraying should be done on top hamper at 7-10 days interval following each plucking round till the disease disappears. Normally 4-6 rounds of COC are necessary in Darjeeling where the disease appears regularly from July to September. In Assam and Dooars the spraying can be discontinued once the damp-weather condition is over and it becomes hot and sunny for a few consecutive days.

Young nursery plants should be protected by spraying at 7 days schedule. The disease often becomes disastrous if it coincides with the bud break of light pruned or medium pruned teas. Under such circumstances, it is advised to protect the new growth by spraying a couple of rounds at shorter interval (say 5-6 days round).

If the attack takes place before the tea is tipped, the initial tipping should be done below the predetermined level. The tea should be then sprayed to protect the tender growth below the table at the usual 6-7 days interval. The plucking table should be subsequently raised to the intended level once the danger is over.

Calixin, a tridemorph systemic formulation, should be applied prophylactically @ 200 ml/ha for 2 rounds at 15 days interval before the advent of rainy days. Prophylactic treatments should be given whenever the environment becomes favourable for the disease and initial symptoms of transclucent circular oily spots appear on the tender foliage. First round of copper fungicide should be also sprayed before the advent of a heavy infection of the disease to achieve a better control.

Field Management : Though ultimate control of the disease is through fungicidal treatment, certain field management practices mentioned below go a long way in reducing the incidence.

1. Black plucking should be the motto when the disease appears in areas under plucking.
2. Shade should be optimum and should be thinned out in overshaded area.
3. Movement of pluckers should be restricted so that they do not enter into the uninfected areas from the infected ones.
4. In case of autumn infection, affected areas should be pruned, skiffed or slashed early.
5. In minor infection, the affected leaves are better pulled off and destroyed.

Black Rot : Black rot is an important leaf disease caused by two fungi viz. *Corticium theae* and *C. invisum*. Both the fungi produce similar effect on the bush and sometimes occur together. They attack the leaves, and kill them, causing gradual deterioration in the health of the bush and consequent loss of crop. The disease is first noticeable in June/July, although germination from the sclerotial stage starts in April/May. The fungus remains active right up to September and then overwinters in sclerotial form in the cracks and crevices of the stem. Transformation into sclerotial stage is a means for survival in the unfavourable weather condition. When favourable condition prevails they germinate and reinfect.

Control measures : Efficient control of the disease is achieved by spraying copper fungicide at 1:400 dilution at fortnightly interval in two repeats during mid April-May, taking special care to wet the underside of leaves and stems. Thereafter when the disease symptoms appear in June/July, individual bush spray depending on the incidence is to be undertaken.

Treatment to supress the sclerotial formation is necessary to snap the survival link of the disease. Carboxin 75%, a systemic fungicide, @ 1:400 is effective in inhibiting sclerotial formation. Control measures consist of usual copper spraying during the active phase (April/May), followed by spraying with two monthly rounds of any of the sclerotial suppressants in the late season (October-November). Two monthly rounds of COC in place of Carboxin formulation also appeared to have provided similar suppression of sclerotia.

During recent years *Bacillus subtillis*, a tea phylloplane bacterium, has been found to be effective in controlling black rot disease of tea. A formulation of the bacterium developed at Tocklai was tried extensively in the field and it achieved similar trend of control as with standard copper oxychloride. This bioagent was found to be effective during both dormant and active phases of the pathogen.

Field management :

1. Incidence of the disease is less in pruned tea as pruning physically removes most of the pathogen. Skiffed and unpruned conditions are more favourable for the disease.

2. The disease thrives best in heavily shaded places especially where the free ventilation is restricted by jungle or bamboo close to the tea. This should be corrected in areas affected by the disease.

3. Shorter pruning cycle can be adopted for chronic and severely affected sections.

4. Alkaline wash after pruning is very effective in reducing the incidence in the following year.

STEM DISEASES

Red Rust

Red rust is the most serious secondary disease of tea in North East India, caused by an alga *Cephaleuros parasiticus*. The disease can cause considerable damage to young tea during the formative years by causing die-back of branches.

Early in the season (March-April) the diseased plant presents a 'thin' appearance, and on severely affected plants the buds either fail to come up or make a poor start and die. The fructifications appear between mid April and mid June in the form of rusty patches on the stems, and variegated and bleached shoots appear on the branches. The disease persists on the bushes from year to year and the affected bushes fail to develop.

Control measures : Spraying is done during the sporulating period of the alga (end April to June) is meant to destroy the spores produced and also to prevent the new growth from being infected. The infected new growth would show the disease only in the following year by producing spores in April-June, and once the alga is inside the host tissue it is unaffected by fungicide treatment. Copper oxychloride formulations are found most effective against the disease. The chemical is applied hitherto at 1 in 400 parts of water with a hand operated sprayer in four rounds, the first two at fortnightly and the subsequent ones at monthly intervals, beginning usually from the end of April. Lower dilution at 1:1000 at six fortnightly rounds provides equal control as 1:400 in four rounds. However, with lower dilution, the spraying must be carried out strictly at fortnightly intervals without missing a single round. Some of the salient features which have emerged in our studies are :

1. The control of red rust by fungicidal application provides 10 per cent increase in yield as compared to untreated control during the first year of treatment.

2. The optimum development of inoculum potential in the atmosphere takes place when the weekly average temperature is 33°C and above, average humidity 77 per cent and above, rainfall not above 150-160 mm and mean sunshine hours not less than 4 hours per day.

3. Urea and MOP at 2 per cent dilution when mixed with copper fungicide solution and sprayed on to the bushes, the health gradually improves with better control of the disease.

Field Management : Red rust is a disease of weakness and its appearance is always influenced by some unsatisfactory cultural and/or environmental conditions. The predisposing factors are identified as poor drainage, low soil fertility, low potash status of the soil, improper soil acidity, lack of shade, continuous use of green crop like *Tephrosia candida*, *T. vogelii* etc. which serve as alternate hosts and also susceptible nature of planting material. It is imperative in the control of red rust to pin-point the predisposing factors and rectify them.

Branch Canker and Thorny Stem Blight

Branch canker and thorny stem blight are two other important stem diseases of tea in N.E. India. Branch canker is caused by *Poria hypobrunnea* and the causal organism of thorny stem blight is *Tunstallia aculeata*. Both of these are typical wound parasites and enter the tea plants normally through heavy pruning cuts. Hence it is necessary to protect the fresh wounds with protective paints to stop the entry of these pathogens. For an effective control of both these diseases careful removal of all dead wood at each pruning and painting of the larger pruned surfaces with a bituminous paint are necessary. One round of protective fungicide spraying with copper oxychloride immediately following pruning (within 24 hours) is also advisable.

Non-pathogenic microorganisms have been utilised in recent times in biological control of many plant diseases. Field and laboratory trials made since 1986-87 have shown that *Trichoderma viride* and *T. harzianum* are two potential bioagents which can be successfully utilized to control branch canker of tea caused by *Poria hypobrunnea*. The bio-agents were propagated in a carrier medium and applied as spore suspension on freshly pruned surfaces. Histological and cultural studies carried out at regular intervals have conclusively proved that once introduced in the wound tissue the bio-agents establish firmly and provide effective barrier against subsequent invasion by the pathogen.

ROOT DISEASES

Primary Root Diseases

The most common primary root diseases in the plains of N.E. India are charcoal stump rot and brown root rot. Black root rot is frequently found in Darjeeling gardens. Red root rot and tarry root rot are of rare occurrence.

The root disease fungi are not host specific. These can spread by means of direct contact of diseased roots or from diseased woody material, though the spread of charcoal stump rot and tarry and black root rots may take place by means of air borne spores as well. The diseased materials may also be carried by rain resulting in spread of the disease in healthy teas.

Unfortunately, there is no known method of detecting root infection by examination of the above from ground portion. Depending on the age and size of the bush, it may require six months to four years to kill a plant. It is not uncommon to find large area infected by these diseases, if proper attention is not paid in the early years of infection. It must be mentioned that

the tea roots remain in close proximity and, by the time a dead plant is noticed, it is probable that its immediate neighbours have also become infected.

Field Management:

1. When the disease occurs on individual bushes or in a patch, there is required uprooting of the diseased bush(es) together with a ring of apparently healthy bushes and removal of all roots.

2. When a large area is involved and immediate action is not possible, the diseased patches should be isolated by 90-100 cm deep and 30 cm wide trench until uprooting can be undertaken. This trench should be connected to the nearest drain.

3. In case of old tea due for uprooting, only the diseased plant is to be uprooted and the whole area should be isolated by an encircling trench as described above. The area should be uprooted two years before replanting.

4. All the vacant areas thus created should be kept under a green crop for two years before infilling or replanting.

Chemical control: In field trial conducted over the years the soil fumigation has successfully controlled the root diseases. Fumigation saves the uprooting of suspects and enables replanting after 12 weeks. Unfortunately none of the fumigants is available in the market for application.

Biological control: In our recent study we have utilized *Trichoderma* bioformulation for control of charcoal stump rot and brown root rot diseases and recorded about 60 per cent reduction of infection. Regional field trials are in progress.

Secondary Root Diseases

Violet root rot caused by *Sphaerostilbe repens* is very common on stiff and clayey soils. It can attack only when the plants are subjected to waterlogging or poor aeration of the soil. These conditions are mainly due to flood, low lie of land, high water table, faulty drainage, depression around the collar region, etc. Improvement in soil aeration is sufficient to prevent this disease.

Diplodia commonly attacks weak plants. The fungus can live on dead plant tissue and is easily the most common invader of dead snags on the frames and root system of the bushes. Affected stems/roots have streaky bluish discolouration in the wood. The fructifications of the fungus appear as minute black dots on the surface of the root/stem. This pathogen attacks the weakened roots, especially those deficient of reserves in poor wet soils and even in sandy soil with high pH. Healthy plants are not affected by this fungus.

SPRAYING EQUIPMENT - MAINTENANCE AND OPERATIONAL REQUIREMENTS FOR OPTIMUM EFFICIENCY

M. C. Borthakur and S. K. Pathak

SPRAYING EQUIPMENT

Spraying equipment or sprayers are the devices for efficient and uniform distribution of droplets of pesticidal/nutrient formulations to control pests or to ensure better plant growth.

TYPE OF SPRAYERS

Sprayers are of different types. Their working principle is mainly based on three basic forms of energy that break up the bulk liquid into the form of a spray. Accordingly, sprayers can be classified as described below.

Hydraulic Energy Sprayers

Pressure retaining type : In this type the air is compressed in a closed container partially filled with spray liquid and, when the trigger is pressed, the stored pressure forces the liquid along the hose.to the nozzle which discharges the fluid in the form of a spray. This type of sprayer is known as **compression** or **pneumatic sprayer**, e.g. Knapsack, Holder Harriden, etc.

Non pressure retaining type : In this type the pressure is developed by the direct action of a pump on the spray fluid. A syringe is a simple example. In the modified form a displacement pump is mounted inside or outside the tank or container. The spray liquid is drawn by a suction force from the container through a non return valve and forced through the second valve into the pressure cylinder. In the pressure cylinder, a pocket of air is present which compresses the volume of the liquid. When the cut off valve or the trigger is operated, the air pressure forces out the liquid through the discharge hose to the nozzle. In such sprayer, more or less continuous pumping is necessary and hence called a non pressure retaining type, e.g. Bak Pak, Nap Sak, Hi-tech, etc.

Gaseous Energy Sprayers

In this type a blast of air is used to atomize the spray fluid in the form of a mist. In power operated gaseous energy sprayer, pressure can be produced by a piston with a fan from the motor driven compressor. Air is drawn into a fan casing at high speed and it is discharged through a flexible tube in which liquid flow nozzle is mounted. The action of high velocity air stream at about 170 mph (270 km/hr) shears the spray fluid which is trickling down through the nozzle, atomising the drops of liquid into finer forms and throwing the droplets to a long distance. The rate of discharge varies from 30-120 litres/hour with particle size 50-150 um VMD. The motorised knapsack mistblowers are of this type.

Centrifugal Energy Sprayers

Centrifugal energy is derived from the rotation of flat, concave or convex disc, a small woven wiremesh cage or a perforated sleeve. This being modified with a toothed circular disc revolves at a high speed discharging the spray fluid through the periphery of the toothed disc. The particle sizes become very small 5-50 μm VMD. The CDA sprayers like Micron ulva, Ecomax, etc. are of this type.

PARTS OF SPRAYERS

Hydraulic Energy Sprayers

The important parts of a hydraulic energy high volume sprayer are : (1) Tank, (2) Strainer, (3) Pump, (4) Pressure chamber, (5) Agitator, (6) Lid with washer, (7) Hose, (8) Spray lance . (9) Cut-off device and (10) Nozzles.

Gaseous Energy Sprayers

The parts are : (1) Fluid tank, (2) Strainer, (3) Petrol tank, (4) Petrol cock, (5) Plug, (6) Hose, (7) AMN nozzle, (8) Microniser, (9) Discharge disc and (10) Power source

The important accessories are : (1) Starting rope, (2) Plug spanner and (3) Filler gauge.

Important parts of both hydraulic and gaseous energy sprayers are discussed below :

Tank

The size of a tank varies with capacity But it must be noncorrosive, being made of stainless steel, brass, HDP, etc.

Pump

Pump plays an important role in atomizing the spray fluid. The various types of pumps in use are described below.

Air pump : It forces air into the airtight fluid tank of a compression sprayer and does not pump the liquid directly. The compressed air in the tank exerts pressure on the spray fluid which is then pushed to the discharge line.

Positive displacement pump : This type of pump takes in a definite volume of the spray fluid from the inlet and transfers it to the outlet without any possibility of escape.

Centrifugal or impeller type pumps : These pumps are used in spray blowers, where droplets are carried by a blast of air. A centrifugal pump consists of a multi blade impeller which rotates at a high speed around a central axis. The pump takes in the air at the axis and throws it by centrifugal force to the periphery where it is collected by the casing (scroll) and is directed to the outlet.

Agitator

The main function of agitator is to keep the pesticide uniformly stirred in the spray solution. This can be achieved through automatic hydraulie agitation or by mechanical agitation.

Power Source

Two or four stroke internal combustion engines are most commonly used in the power-operated sprayers. Electric motors may sometimes be used to provide power for stationery or semimobile sprayers. Battery operated lightweight portable sprayers and Electrodyne sprayers are also available now-a-days.

Pressure Gauge

Pressure gauge is used to monitor the pressure during spraying. It should be connected to the pipeline as near the nozzle as possible.

Valves

Valves govern the direction of the flow of the spray fluid. They are fitted into the pipe system, so that they allow the liquid to pass in the direction of the nozzles.

Filters (Strainers)

A strainer made of fine gauze is generally fitted beneath the tank-filler cap to filter the spray fluid. There may be several filters usually provided between the tank and the pump unit, between the pump and spray lance and within the spray lance. It is sometimes even fitted in individual nozzle.

Pressure Chamber

It is provided in sprayers operated with hydraulic pumps to prevent the fluctuations in the pressure and hence it maintains uniformity in spraying.

Hose

The hose in a hydraulic sprayer is the connecting pipe between the spray tank and the lance. It should be light, non-absorbent, oil resistant, durable and flexible. Its bursting pressure should be over three times greater than the spraying pressure. The commonly used materials are plastic and nylon. Nylon-braided plastic hoses are also available. In gaseous energy sprayer a large plastic flexible tube is used to discharge the air flow. At the tip a liquid flow nozzle is connected. This nozzle is connected to the fluid tank separately through a small plastic tube.

Spray Lance

This is an extension rod of 35 to 90 cm in length, made of brass which is hollow internally and used in high volume sprayer. One end of the lance is fixed to the hose while the other to the nozzle. Usually it has a 120° bend to form a goose neck near the nozzle.

Cut Off Devices

Cut off valves are provided to shut off the flow of the liquid. They are either spring or knob operated.

Nozzles and Other Atomizing Devices

Nozzle is the most important component of a sprayer. It has three major functions : (1) it breaks up the liquid into fine droplets, (2) the droplet size and the spray release pattern are guided by the nozzle and (3) it restricts the flow of the spraying liquid.

Structure of Typical Hydraulic Energy Nozzle

The hydraulic energy nozzle used in a high volume sprayer essentially consists of a small chamber with a device inside it to atomize the liquid before it comes out of the orifice. Some nozzles are of integral construction, whereas others are made up of several components as described below.

Body of the nozzle : This is a piece of brass hollowed internally with threads at both the ends for fixing the nozzle with the cap at one end and to the extension rod at the other.

Cap : It holds the strainer wherever present, orifice plate, washer and swirl plate in position. The cap and the orifice plate may sometime be in one piece.

Orifice plate : It is also called discharge disc with an aperture of different diameters at the centre. During continuous use the orifice enlarges and the volume of spray and the spray pattern change considerably from the original. So the discharge rate should be checked periodically.

Swirl plate : The function of the swirl plate is to give a definite characteristic of the spray pattern. The 2-hole swirl plate is common, but some have several holes. The holes are slanting in order to produce the whirl effect. Alternatively, the swirl plate may have a spiral screw thread. A hole in the centre of the spiral plate produces a solid cone spray pattern.

Washers : These are of various thicknesses to allow variation in the depth of the Eddi chamber and to prevent leakage of the spray fluid.

Strainers : Certain nozzles may be equipped with strainers to prevent the exit of bigger solid particles through the orifice so that no blockage of nozzle is caused.

Types of Nozzles

Though nozzles can be classified in various ways, the functional classification is as follows (Fig. 1).

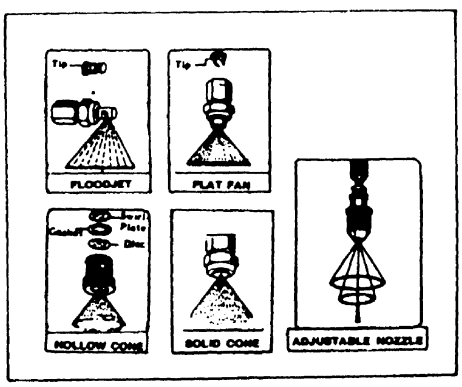

Fig 1. Hydraulic nozzles with spray patterns.

Jet or solid stream nozzles : These possess a simple exit hole or a tube designed for producing a jet that finally shatters into coarse drops, e.g. Jet nozzle, Triple Action Nozzle.

Impact or floodjet nozzles : These are also known as deflector nozzles. A jet of liquid strikes a smooth solid surface at a high angle of incidence to form a fan shaped spray pattern. Droplet size is large (VMD > 300 μm). It produces minimum drift and is used for weedicide application.

Flat fan or fish-tail nozzles : Their spray pattern is in form of a flat sheet like a hand fan and these are used for weedicide application.

Cone or swirl nozzles : In these nozzles the spray fluid rotates owing to its passage through a spiral groove or tangential holes. An air core is formed within the orifice and swirl plate (eddy chamber) because of sufficiently high rotational velocity of the spray fluid. Thus a hollow cone of liquid is formed. These are commonly used for spraying insecticides and fungicides.

In the solid cone nozzles, the liquid also passes centrally through the nozzle to fill the air core to produce a solid cone spray pattern.

The basic differences among flat fan hollow cone and solid cone nozzles are given in Table 1.

Table 1. Differences in the flat fan and cone nozzles.

Character	Flat fan nozzle	Hollow cone nozzle	Solid cone nozzle
Swirl plate with holes cut into it at angles or a cylinder with spiral slits	Absent	Present	Present (additionally an orifice is present in the centre of a plate or cylinder)
Comparative size of swirl chamber	Absent	Large	Small
Shape of orifice	Lenticular or elliptical	Circular	Circular
Comparative droplet size	Very large	Small	Smaller

Triple-action nozzles : They can produce a jet, solid cone and hollow cone i.e., three types of spray patterns on adjustment.

Low volume nozzles : The low volume nozzles are used to spray more concentrated fluid in finer droplets. These have a range of discharge plates with 0.5 l, 1.0 l, 1.5 l and 2.0 l discharge capacity per minute to control the flow of spray fluid. But for ULV or LVC the restrictor nozzle can be used.

OPERATIONAL REQUIREMENTS FOR OPTIMUM EFFICIENCY

VOLUME OF SPRAY Vs DOSE OF PESTICIDE

The quantity of spray fluid required per unit area varies depending on type of sprayers used. But the dose of pesticide per unit area remains constant irrespective of quantity of spray fluid applied.

High Volume Spray

High quantity of spray fluid is required per unit area, i.e. more than 200 l/ha with large droplets (300-400 μm). The drip loss or run off is common. All commonly used hand sprayers are high volume sprayers. These are preferred in young tea below five years, shade nurseries and against certain pests like jassids, scarlet mites, nettle grubs, helopeltis, termite, caterpillars and for weedicide application.

Low Volume Spray

Low quantity of spray fluid is applied in fine droplets (50-150 μm) at a higher concentration and suitable for insecticide and fungicide application. Motorised knapsack sprayers are commonly used for low volume spray. There is virtually no run off loss.

Because of deep penetrating effect, low volume sprayers are often considered more efficient on particular situation. Low volume spraying is suitable against thrips, helopeltis, looper caterpillar, etc. Sometimes to ensure coverage of large area within a short period, this sprayer is found suitable. For blister blight control low volume spraying can be used but at a higher discharge rate i.e. 60-90 l/hr.

Ultra Low Volume Spray ULV

The undiluted pesticide in special formulation is applied in very fine droplets (30-100 μm) by ULV applicators. This type of spray is suitable for insecticides only. The quantity applied is usually within 1-1.5 l/ha for field crops. The distribution of such small droplets depends on gravity and air movement. Most of the aerial applications are done with ULV formulations. In this type of application, the time requirement is much less and the spray deposits persist longer. In water stress areas ULV may be suitable. ULV application can be made by motorised knapsack sprayer fitted with restrictor nozzles or by aircraft with special nozzles.

QUANTUM OF SPRAY FLUID REQUIRED

A general guideline on the requirement of spray fluid per hectare in relation to kind of sprayers used and types of tea is presented in Table 2.

Table 2. Requirement of spray fluid per hectare.

Type of pruning	Hand operated high volume sprayers		Mist blower low volume sprayers
	Pests	Diseases	
Pruned tea	200-350 l	400-600 l	100-150 l
Skiffed tea	350-500 l	600-900 l	200-250 l
Unpruned tea	500-700 l	900-1200 l	250-300 l

COVERAGE OF AREA

Spray coverage varies with the type of sprayers. With high volume spray an area of 0.3-0.4 hectare can be covered in a day as compared to 1.5 hectare with low volume spray per manday.

DOSE, DISTRIBUTION AND TARGET COVERAGE

The biological efficacy of a pesticide is primarily influenced by three factors i.e., the mean level of deposit (dose), distribution of the deposit and the coverage of the target.

Generally in pest control situation adequate coverage of plant is desirable. The density of droplets per unit area, droplet size and the deposition of chemical are important. The nature of the pest and the mode of action of pesticide helps to determine the degree of coverage needed for effective pest control. Pests which are static like aphids, scale insects, mealybugs or even scarlet mites require continuous coverage of the plant to reach all the insect population, if contact insecticides or acaricides are used. Similarly, stomach poisons also require good coverage because the pesticide must be ingested in sufficient quantity by the pest to be toxic. In case of these pests large volume of spray fluid is required to cover the infested surface. Effective coverage can also be obtained with a large number of minute droplets. On the other hand, systemic insecticides which are absorbed into the plant system require a moderate dispersion and a good coverage is not very important. In case of diseases, high volume spray is required for the control of fungal pathogens like black rot, red rust and also blister blight.

TARGET OF SPRAYING

Depending on the site of attack by various pests and diseases and their habitat, the target of spraying also varies. (Tables 3 and 4).

Table 3. Target of spraying for major tea pests.

Pest	Target of spraying	Remarks
Red spider and purple mite	Both surfaces of leaves of the whole canopy	Thorough coverage is necessary
Pink mite	Both surfaces of leaves of tip and middle hamper	- do -
Scarlet mite	Lower surfaces of leaves and the stems of whole canopy	Spraying should be done from the older leaves to young ones
Thrips	Tender shoots, lichens and mossess, cracks and crevices of the frames and soil surface	Spraying should be thorough
Jassids	Lower surface of leaves of top and mid hamper	- do -
Tea mosquito bug	Whole canopy, weeds and soil surface	Barrier spraying is necessary
Looper caterpillar	Whole canopy, and shade tree trunks	Spraying should be done at early stage of growth. Thorough coverage is necessary
Bunch caterpillar	Mid and bottom hampers of the bushes	Spraying should be done at early stage of growth
Red slug caterpillar	Mature leaves of whole canopy, young stems and trunks of shade trees.	Barrier should be given by used engine oil to prevent migration
Termite	Whole frames, including collar and soil around collar region	Spraying should be done after removal of earth runs

Table 4. Target of spraying for major tea diseases.

Disease	Target of spraying	Remarks
Blister blight	Top hamper of the maintenance leaves	Thorough drenching is necessary
Red rust	One or two years old stems and laterals	-do-
Black rot	Undersurface of leaves, leaf petioles, stems of primary shoots	Only the diseased bushes should be sprayed
Poria	Protection of any wound surface	Cut surfaces should receive protective cover immediately after pruning

SELECTION OF NOZZLE

Table 5. Nozzles for specific situation.

Target of spraying	Suitable nozzle	Code No.	Spray angle in degree	Discharge per min. in ml.	Pressure in p.s.i
Tea bushes	Duro Mist	NMD	60	450	40
	Adjustable	BAN	75	450	40
	*Back to back		60	900	40
Shade trees	Adjustable	BAN	75	450	40
	Triple Action	NTM	70	570	40
Weeds	Floodjet	WFN/24	25	172	10
	Floodjet	WFN/40	40	470	10
	Floodjet	WFN/62	95	1230	10

* For black rot and red rust

Droplet Size and Density of Droplet

The optimum droplet size is defined as that which is small enough to be produced in large number for maximum coverage and large enough to have suitable impinging capacity for reaching the target with minimum drift.

The pattern of droplet size and droplet distribution is collectively termed as **spray spectrum**. On the basis of the size of particles, spray patterns can be classified as in Table 6.

Table 6. Spray patterns on basis of particle size.

Type of discharge	Equipment used	Approximate range of particle size (μ)
Course spray	Hydraulic sprayer	More than 400
Fine spray	Hydraulic sprayer	100 - 400
Mist	Mist blower	50 - 150
Fog	CDA	5 - 50
Fog	Aerosol generator	0.1 - 50
Smoke	Smoke generator	0.001 - 0.1

For efficient deposition the droplet spectrum should be narrow. With larger particles say above 400 microns run off loss will be more, and with smaller particles say below 100 microns drift will be more. When droplet size is bigger, number of droplets are few, penetration and coverage are poor with smaller swath. Hence, requirement of spray fluid is more. But drift and evaporation are less with bigger droplets. The situation is reversed with smaller droplets. Droplet size can be manipulated to our advantage by changing the spray condition i.e. orifice size, spray angle and pressure. To get finer droplets orifice size should be reduced but spray angle and pressure should be increased. The condition is reversed to achieve bigger droplets.

Function of droplet size on number of droplets, terminal velocity, coverage and evaporation rate is presented in the Table 7.

Table 7. Influence of droplet size.

Droplet diameter (μm)	Number of droplet/l X 10^7	Terminal velocity cm/Sec	Crop surface area/litre (m^2)	Spray fluid required/ha	Relative rate of evaporation
300	7.1	122	20	500	1
150	56.6	72	40	250	3
100	191.0	26	60	167	8
50	1527.9	7	120	83	40
10	190985.5	0.9	600	17	-

Source : Oudejana (1991)

DO'S WHILE SPRAYING

1. Application during ideal weather condition.
2. Reduction of distance between the nozzle and the target (30-45 cm).
3. Directional spraying in case of diseases and pests like red spider, thrips, looper caterpillar, etc.
4. The height of operator should match the height of tea bushes.
5. Ideal droplet size by using recommended nozzles and optimum pressure.
6. Timely cleaning of nozzle.
7. Using a protective shield where necessary.
8. Application of pesticide in early morning or late afternoon hours.
9. Application of pesticide soon after plucking.

DON'TS WHILE SPRAYING

1. Spraying should not be done when wind velocity is 8 km/hr or more to avoid drift and thus environmental pollution.
2. Avoid spraying under strong sunshine.

MAINTENANCE OF SPRAYING EQUIPMENT

BEFORE SPRAYING

1. All components should be cleaned - especially filling and suction strainer, sprayer tank, cut-off device and nozzle.
2. Worn out parts like 'O' ring, seal, gasket, nozzle tip, hose clamps and valves should be replaced prior to spraying. Any leakage through worn out parts will cause wastage of costly chemicals and also contaminate the body of the operator.
3. All components of the nozzle must be intact and the spray pattern should be checked.

DURING SPRAYING

1. Only required quantity of pesticides should be taken to the field.
2. Proper dilution of chemicals with water is to be ensured.
3. Appropriate clothing and cover should be used to protect skin, eyes and mouth from contamination.
4. Operator should not eat, drink or smoke.
5. Proper supervision to maintain all the preconditions.

AFTER SPRAYING

1. Equipment should be properly cleaned followed by lubrication and then kept away in one corner of the store room.
2. Empty containers should never be used for any purpose but to be crushed and buried deep in wasteland.
3. All other containers, measuring jars etc. and all the clothing should be washed at the end of the day's operation.
4. Sprayed plots should be marked with a flag indicating the application of pesticide.
5. Persons involved in spraying should take bath with soap and lukewarm water after the day's work.
6. In case of power sprayers instructions and service chart given by the manufacturer should be followed to maintain them properly.

PESTICIDE POISONING

All pesticides are poisons. The risk of poisoning is very less if necessary safety measures are taken while working with pesticides. However, the possibility of an accident can't be ignored. It is always better to take help from a medical personnel, if such an accident occurs. For prompt treatment, information on specific symptoms of acute poisoning by commonly used group of pesticides and treatment with antidotes are given below.

General Symptoms and First Aid for Acute Poisoning

Mild poisoning : Headache, dizziness, tiredness, irritation of skin, eyes, nose and throat, diarrhoea, excessive perspiration, loss of appetite.

Severe poisoning : Blurred vision, constricted pupils, stomach cramps, vomiting, difficulties in breathing, profuse perspiration, tremors and jerking of muscles, twitching.

Extremely grave poisoning : Convulsions, loss of consciousness, breathing stops, no pulse.

First aid :

1. Contaminated clothes should be (if applicable) removed. Exposed part of the body should be washed with water.

2. Mouth to mouth respiration is to be given if breathing has stopped.

3. If convulsions occur, care should be taken so that the victim does not hurt himself. A rolled-up handkerchief or peice of wood may be placed between the teeth to prevent biting the inside parts of the mouth. Victim should be turned on to his side placing a pillow under the head.

4. If poison is taken in by mouth, it is generally not advisable to iduce vomiting except in case of extremely toxic pesticides.

5. A doctor should be called immediately or the victim should be hospitalised.

First aid kit :

It should contain at least the following :

1. Special bottle for washing the eyes
2. Active carbon
3. Soap
4. Vitamin K1 tablets if anticoagulant rodenticides are regularly used
5. Atropine sulphate
6. Several sterile injection syringes

Specific Symptoms and Treatment

Anticoagulant rodenticides :

Specific symptoms : Increased tendency to bleeding from nose, urinery tract and intestines. In serious case, bleeding of the internal organs may also occur which can be fatal. Skin lesions may also occur (bruising) after 24-28 hours.

Treatment : Vitamin K1 tablets (intravenously in severe poisoning) 10-20 mg maximum 40 mg/day. In severe cases, it may be necessary to induce vomiting or to pump out the stomach. Blood transfusion may be necessary.

Organophosphates :

Specific symptoms : Inhibition of cholinesterase, tears, excessive saliva, profuse perspiration, constricted pupils, twitching of muscles etc.

Treatment : The antidote Atropine Sulphate is administered by injection @ 2-4 mg for adults at every 3-10 minutes until complete atropinazation is achieved (dry mouth, dilated pupils). After or during atropinazation an oxime such as 2-PAM or P2S (Contrathion) is administered @ 1000/2000 mg intravenously or intramuscularly for adult. An alternative is Toxogonine (250 mg).

Not to administer : Morphine or other opiates, phenothiazines, succenylcholine, xantive derivatives, epinephrine, barbiturates.

Carbamates :

Specific symptoms : Similar to that of organophosphate, but action in the body is short lived.

Treatment : In severe cases Atropine must be administered.

Not to administer : Oxime such as Toxoginine or Contrathion as in case of organophosphate.

Organochlorines :

Specific symptoms : Headache, nausea, increased sensitivity, twitching. In severe cases convulsions or short periods of loss of consciousness may occur.

Treatment : Apply mouth-to-mouth respiration if breathing stops. There are no antidotes. Convulsions can be controlled with barbiturates (Pentothal, Evipal, phenobarbitone) and/or Valium (Diazepam). Following oral intake, wash out the stomach and administer active carbon into the intenstines. The probability of chemical pneumonia should be kept in mind.

Not to administer : Morphine or its derivatives, epinephrine or noradrenaline. Vomiting should not be induced except when liquid solution of Endrin is taken. Fats, oils or milk should not be given.

Synthetic pyrethroids :

Specific symptoms : Pyrethroids have little danger of acute poisoning. In severe poisoning, convulsons and other effects on the nervous system may occur.

Treatment : Valium (Diazepam) could be administered.

Not to administer : Vomiting should not be induced, if necessary, the stomach could be pumped out in the hospital.

Copper compounds :

Specific symptoms : There is little danger of acute poisoning. Irritation of the gastrointestinal tract can occur if taken by mouth.

Treatment : Stomach wash out, washing of eye or skin with running water continuously for at least 20 minutees if it come in contact with the poison

Chronic Poisoning

A significant form of chronic poisoning caused by organophosphates (OP) and carbamates (CA) is inhibition of cholinesterese (Ache E) an important enzyme of nervous system. So, it is advisable to arrange regular check up of the persons working with these compounds for Ache E level in blood. If it is lowered by 30-50 per cent, further contact with OPs and CAs should be prohibited until the level is again normal.

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IMPORTANCE OF COLD WEATHER OPERATIONS IN IMPROVING PRODUCTIVITY

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INTRODUCTION

Recommended planting materials from century old R and D work of Tocklai with the package of mineral nutrition developed and revised from time to time produced more than 3000 kg/ha at maturity over a pruning cycle in N.E.India. However,such areas are smaller and confined to a few sections in different estates. Proper planning at estate level to maintain better soil physical conditions and fertility status is a basic necessity to achieve high yields. Using suitable planting materials, suitable pruning cycles of 3 years duration in the plains and 4-5 years in the high elevations of hills, good shade, plant protection measures, weed control and drainage will shorten the time in achieving higher yield from planting time.

To achieve a high level of yield, a systematic planning at all stages and attending to details during the cold weather as mentioned here areawise will go a long way in achieving sustained productivity. Cold weather operations when done with perfection, minimise the incidence of pests and diseases in the cropping season.

A. Darjeeling

1. Continuous *thullying* causes collar depression and water logging and hence such depressions should be filled up by March and must be completed by June.

2. Every year in pruned areas, proper demossing using alkaline wash/winter wash oil, knife cleaning and knot removal is advisable. Retention of the pruning litters is to be ensured.

3. Constructions of contour drains where possible and establishing permanent rows of grasses across the slope should be accomplished in pruned areas.

4. Establish permanent grasses like *Vetiver* or weeping lovegrass (*Eragrostic curvula*) across the slope of run-off at 4-5 ft.vertical interval on steep slopes to arrest soil loss.

5. Protect the emerging buds from the sucking pests like aphids, thrips and green flies. Endosulphan 35 EC formulations should be used during the period from bud-break to tipping in 3-4 rounds and in between once Fenvalerate 20 EC or Alphamethrin 10 EC, if necessary, depending on infestation level and weather. Under low level of infestation Endosulfan at a dilution 1:600 mixed with recommended neem formulation will be effective if sprayed as suggested above.

6. Tipping chinary bushes after pruning at 18 cm, Assam types/hybrids at 20 cm, DS over two leaves, MS over one leaf on time to avoid banjhi are important.

7. Banjhi shoots removal soon after pruning is an important operation and this can be done by hand or by using a 7.5 cm knife.

8. Two prophylactic sprayings with Endosulfan 35 EC once in end December and again in end January will provide adequate protection from the attack of thrips. Ethion 50 EC/Dicofol 18.5 EC should be used where infestations of mites are noticed in end January-early February.

9. Phosphate manuring every year 20 kg/ha and foliar spraying with 1% MOP should be done. **Check and amend soil pH regularly.**

10. In view of more than 80% areas above 50 years in age,rejuvenation, interplanting and thereby proper consolidation at a faster rate is very important.Hence, in pruning years, rest the bushes for 6-8 weeks, establish Guatemala, Citronella or *Tephrosia candida* about two years in advance on vacant patches.

11. Establish temporary shade on low elevations and on the southern and western aspects on mid elevations as well about two years before pruning.

12. Treat the frame with 10% spore suspension of *Trichoderma* or do indopasting on the large cuts.

All the above points will be equally useful for Sikkim and other hilly areas of high elevation as is given for Darjeeling.

Plains of Assam, particularly South Bank and North Bank

1. Where pruning litter is not retained and/or shade is poor, special importance should be given to organic matter management through external source like cowdung, compost, oil cakes etc.

2. Levelling of the ground and flattening of drain sides should be done to reduce temporary water logging.

3. Phosphate manuring every year is a must @ 20-50 kg/ha depending on the crop yield.

4. ***Helopeltis*** is slowly gaining ground and hence needs careful monitoring and insecticidal spraying.

5. To obtain timely crop from UP tea, foliar applications of MOP (1%) and $MgSO_4$ (1%) should be followed during January to March.

6. Photosynthesis in tea continues throughout the year. Hence, when soil moisture reaches at only 25% available moisture,an irrigation particularly in young, youngish and mature tea is important.

In addition to these points, bush sanitation measures,termite control and prophylactic spraying against red spider mites must be undertaken.

Cachar and Tripura

1. Land clearing on Teelas should be planned 2 years in advance before planting. Cut down shrubs and trees soon after rains and leave those *in situ*. When leaves are shredded off after sometime, woody materials should be taken out.

2. Provide contour drains and permanent grasses across the slope.

3. In the next year, cleaning drains, infilling of grasses and green crop sowing should be done with pre-monsoon rains. Thus, planting tea on an established stand of green crop and satisfactory check on soil erosion after land clearing is achieved. Proper nozzle and duration of irrigation should be used not to reach the run-off stage to check soil loss during irrigation in autumn planted tea.

4. In existing old teas on teelas, soon after uprooting of old teas and shade trees, contour drains should be renovated during cold weather. Fill up depressions, sow green crop and plant permanent grass lines along the contour. Permanent shade trees should also be planted.

5. Termite treatments should be done properly and even in the planting pit.

Dooars and Terai

1. Lighter MS as in vogue in these areas produce banjhi shoots.decreasing yield and quality. Hence the MS cut should always be below the topmost Crow's feet. This helps to overcome drought also. In drought prone areas DS should be followed instead of MS.

2. In CA pruning at the end of a pruning cycle an allowance of 4 cm in older tea and 5 cm in younger tea for new wood must be given in stead of repeating CA at the same level.

3. Ensure these practices after pruning mature tea :

   a) Alkaline wash.

   b) Collect looper chrysalids from December in infested sections.

   c) Develop cutoff drains where seepage water problem exists.

   d) Cold weather treatment for termite control.

   e) Cold weather forking in heavy textured soil.

4. Spray Acephate/Monocrotophos during end January/end February to control thrips during bud-break.

5. ***Helopeltis*** **continues to be the worst pest and hence close monitoring and control in UP** and **LOS teas are very important.**

6. Leave small 1+buds and 2+buds until the onset of rains during March and April. From May onwards 2+buds should not be left out as the growth is more quicker.

7. Liberal plucking during drought with 6-7 days plucking round in pruned areas and 8-9 days plucking round in unpruned areas should be followed.

An exhaustive write-up has been circulated to all Member Gardens in December, 1997 on the subject. However, in addition to the areawise important points, some general considerations are given here which need attention :

1. A pruning knife weighing at least 450 g should be used. Lighter knife causes wood splitting inviting wood-rot pathogens and termites.

2. Forking the collar region to break top soil compactness helps in improving root aeration and then root growth is faster particularly in heavy textured soil.

3. Hand levelling and banjhi removal of unpruned tea once in mid January and once in mid February is suggested.

4. Control cerambycid borer in shade trees. The adults emerge in February - March or September - October. Precautionary measures suggested are :

   a) Remove dead and decaying trees.

   b) Give priority to reshading programme with

Albizzia lebbek *Acacia lenticularis* *Dalbergia sericea* *Derris robusta* *Adenanthera pavonina*	Mixed in each row, not more than 20% of any one species.

c) Spray chlorphyriphos 20 EC/monocrotophos 36 SL during early February to late April and early May, mid September to mid November covering upto a height of 6 m of the shade tree trunk from the ground.

d) Remove the webs of bark eating caterpillars and pour insecticide solution into the retreat holes with oil cans/wash bottles and close the holes with mud or putty.

5. Maintain strictly the guidelines for pruning/skiffing as follows.

Operation	Timing	Height of operation	Tipping at
MP	End Nov.- Mid Jan	50-70 cm from ground	-
		50 cm and below	35 cm from pruned mark
		55-60 cm	30 cm " " "
		Above 65 cm	25 cm " " "
LP	Early Dec. -Mid Jan.	7 cm above MP (when done after MP)	Over 5 leaves i.e., 25 cm above the cut.
		4-5 cm above last LP	-do-
DS	Mid Dec.- Early Jan.	10 cm after LP tipped at 20 cm	Over 2 leaves i.e., 10 cm.
		12-13 cm when tipped at 25 cm or after one or more UP years	-do-
MS	Early Jan. -Mid Jan.	Below the crow's feet	Over one full leaf.
LOS	3rd week of Jan	-	-
Pruning young tea	Early Jan. -Mid Feb.	As discussed in young tea management	

Note : Small 2+bud should not be tipped in LP whereas in DS and MS tip soon when shoots are ready.

6. Rejuvenation pruning particularly for plains estates should not be programmed for sections which are to be uprooted within next 12-15 years, vacancy more than 25%, not free from root diseases, bushes damaged severely by termite and *Poria* and scope of improving drainage does not exist.

7. Proper bush sanitation in the pruned year reduces hibernation of pests and enhances bud break. Removing earth runs of termites, improving drainage, infilling shade and thinning dense areas and correcting soil pH go a long way in minimising predisposing factors for infestations of insect pests and diseases.

8. Crop sustainability limit for a 3-year pruning cycle is normally higher than a 4-year one. Only on higher elevations like Darjeeling, Sikkim etc. a 4-5 year cycle is recommended.

9. DS and MS done after one or two years of UP results in banjhi formation below skiffing level which need to be removed. Further, 25 cm tipping measure after LP provides adequate thickness of wood for DS.

10. Finally, the knowledge of advanced agro-technology and appropriate plant density (15000 - 16000 in plains and 16000 - 18000 in hills) will reduce the payback period for young tea plantations. Hence, contributions of the 7 important points should be fully realised as follows :

i)	Good standard of plants	-	20 per cent.
ii)	Pruning/Skiffing/Tipping and Plucking	-	25 " "
iii)	Weed control in formative stage	-	15 " "
iv)	Balanced manuring	-	20 " "
v)	Pest control	-	5 " "
vi)	Drainage and levelling	-	10 " "
vii)	Shade	-	5 " "